

THE

ELECTRICAL REVIEW

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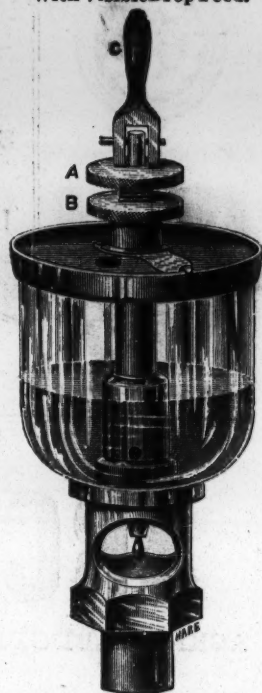
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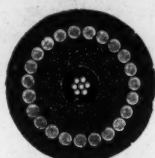
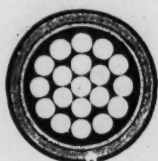
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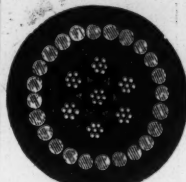
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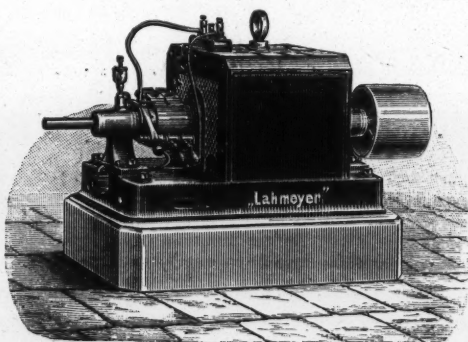
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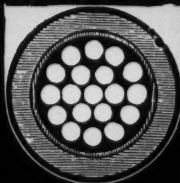
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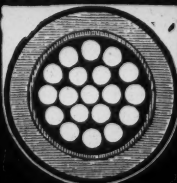
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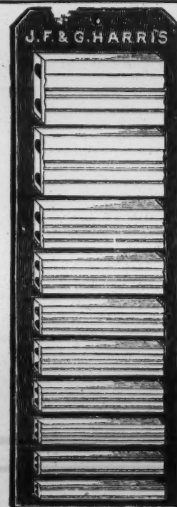
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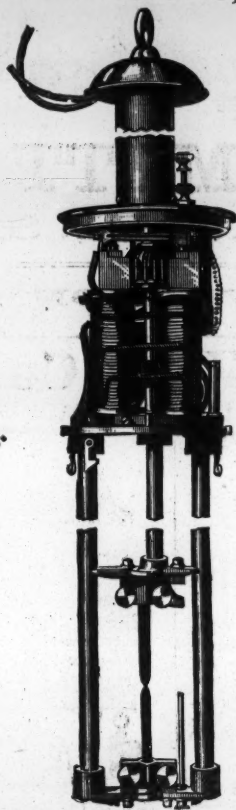
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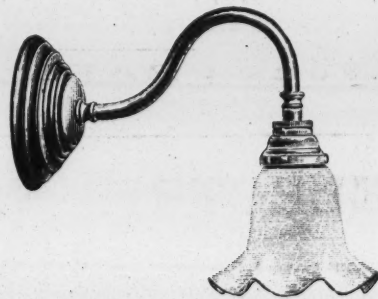
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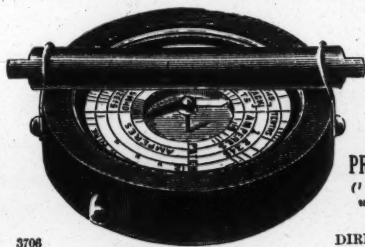
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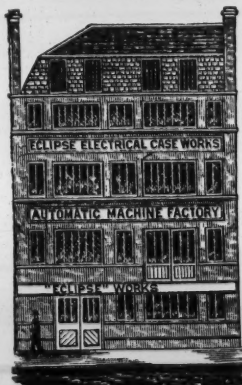
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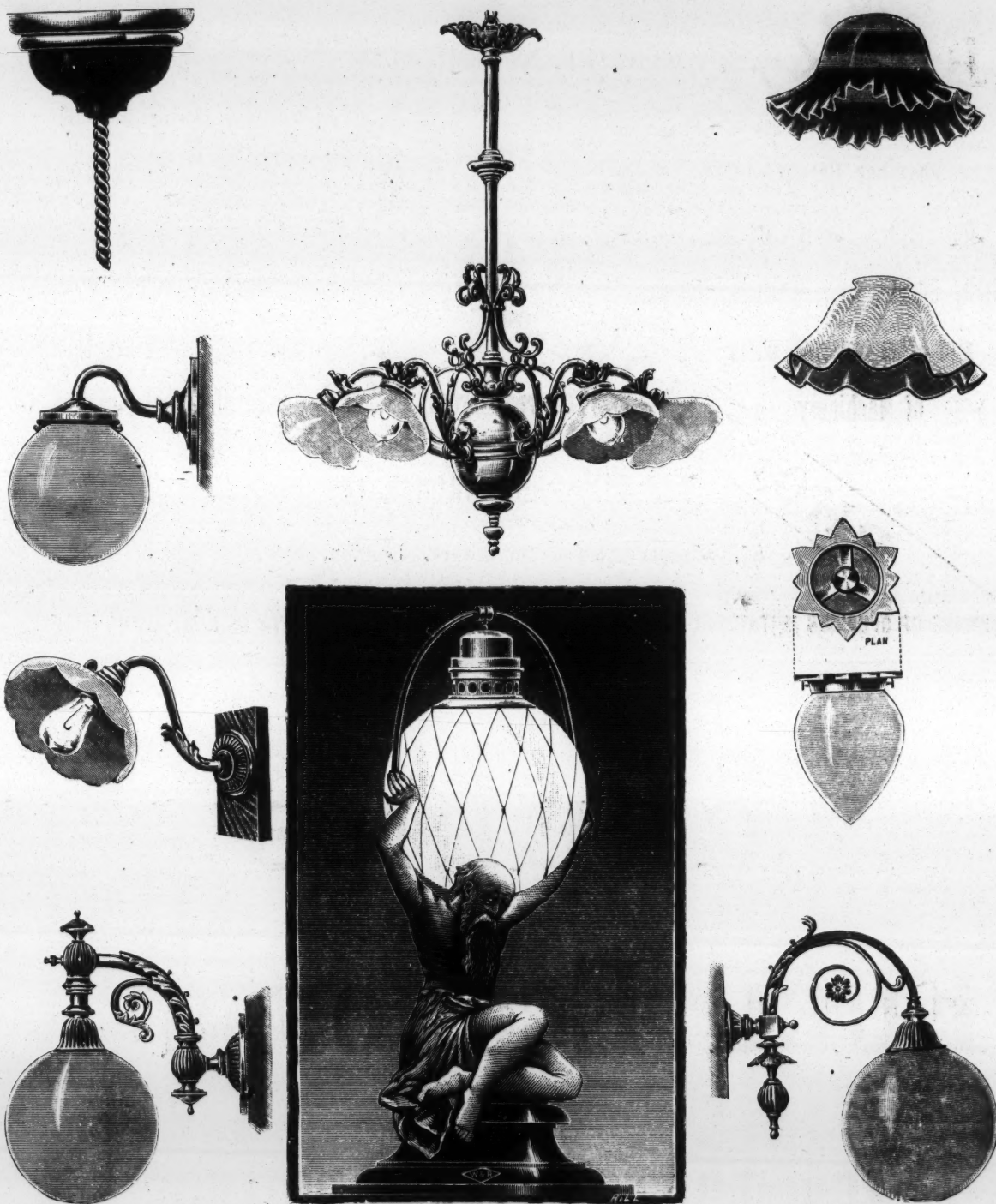
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ELECTRICAL HETERODOXY.

THE leading lights in the science of electricity have, in recent years, made notable progress in the field of electrical theory. Faraday first drew attention to the important part played by the dielectric in all electrical phenomena; and his epoch-making discoveries afterwards received their full mathematical interpretation from the genius of Clerk Maxwell. Some of the remarkable results of Maxwell's investigations have received experimental proof by the labours of Hertz and others. Further developments of theory have been made by Thomson, Poynting, Lodge, and others of Maxwell's school.

In science, as in politics, there is a danger that a great leader may prove the evil genius of his followers, and hence the advantage of a little healthy dissent. Mr. James Johnstone, of Edinburgh, is a prominent member of the class who refuse to accept the recent developments of electrical theory. He is no novice in the study of electricity, for he seceded from the orthodox school more than fifty years ago, differing from Faraday on his theory of induction by polarisation of the atoms of the dielectric, and claiming to have converted him by a letter, sent to him in 1839, to the belief that electricity passes through glass by conduction and not by induction. Mr. Johnstone has expounded his views in two pamphlets, one entitled "The Ether Theory of 1839 is the True Theory of the Leyden Jar," and another entitled "Facts which prove that Faraday's Two Force Theory of Electricity is False." We have also had the privilege of seeing Mr. Johnstone's experiments at his laboratory at Dalhousie Terrace, Edinburgh, and some of these are sufficiently remarkable to be of great interest to electricians. Mr. Johnstone's theory of the Leyden jar differs considerably from that which is generally accepted. In his opinion, *induction* is a myth, and electricity will pass by *conduction* through glass of the best insulating quality. He considers that by his experiments he has proved that in charging a

Leyden jar, electricity passes at first by *conduction*, through the glass, "but the moment the electricity begins to pass by *conduction* through the glass, it immediately acts on the particles of the glass, by increasing their attraction, so far that it has the effect of stopping the passage of the current of electricity through the glass to a slight extent, but the current goes on by conduction at a diminished rate until the increased attraction of cohesion of the glass entirely stops the passage of the electricity." In proof of this thesis, Mr. Johnstone offers the following experiments :—A test tube about 8 inches long and 1 inch in diameter, without any extra thickness of glass at the closed end of the tube, or other imperfection, is slipped on the positive electrode of an influence machine, so that the terminal ball reaches close up to, but does not touch the inner end of the tube; and the ball of the negative terminal is brought within a quarter of an inch of the outside bulb of the tube. On turning the machine, sparks are seen to pass from one terminal of the machine to the other, through the substance of the glass, and on examination the tube will be found to be quite free from perforations. This unexpected result can easily be obtained by anyone who chooses to repeat the experiment. In another experiment Mr. Johnstone sends positive sparks into a Leyden jar, supported horizontally on insulating pillars, and having a break in the wire connecting the outer coating to the earth. The direction of the current in the sparks entering the inner coating and leaving the outer coating of the Leyden jar are indicated by insulated gas flames placed in the path of the sparks. It was discovered by Mr. Johnstone in 1839 that these flames are deflected in the direction in which so-called positive electricity is passing. At the commencement of the charging, positive electricity is found to leave the outer coating apparently at the same rate as it enters the inner coating, but at the end of the operation the discharge from the outer coating gradually falls off and finally ceases. If a wire is passed through the stopper of the jar, so that part of the wire passes into the interior of the jar,

while the outer end is pointed and bent at right angles till the point projects over the edge of the jar, Mr. Johnstone finds that as long as positive electricity is passed into the interior of the jar, positive electricity continues to leave the outer coating. This does not stop as in the former case, but may be continued for any length of time.

Now, do these experiments necessarily prove that electricity passes through glass by *conduction*, and that *induction* is a myth? With all respect to Mr. Johnstone, we think not. The experiment with the test tube is a remarkable one, and it will be new to most electricians to see the electrical spark apparently passed through glass without perforating it. We have ourselves repeated the experiment, and we believe that the following explanation is correct. In the case of all the test tubes we have experimented with we have found that even when thoroughly dried they are comparatively good conductors for the electric spark from an influence machine. Hence, in the experiment described above, when the spark from the positive electrode of the influence machine strikes the interior of the test tube, an equal quantity of electricity must leave the outer coating; just as when a billiard ball strikes one of two billiard balls lying in contact the outer ball will be driven off without apparently producing any movement in the ball which was struck. The charge imparted to the inner surface of the test tube is now quickly dissipated by conduction, and the interior of the tube is ready to receive another spark with exactly similar results. In the case of a Leyden jar with glass of good insulating quality the first spark of electricity imparted to the inner coating will cause a similar spark to leave the outer coating, but the second, third, or some succeeding spark will cause a spark to leap from the inner to the outer coating, through the mouth of the jar if the jar is open mouthed. This last result, it appears to us, completely explains the action of Mr. Johnstone's pointed wire. The wire being a conductor and pointed, reduces the resistance of the path between the inner and outer coatings of the jar, and permits the electricity to flow between them, even when the potential is much below its maximum with the ordinary arrangement of the jar.

Mr. Johnstone, in his book, also discusses the classical experiment employed to show the phenomenon of electrostatic induction, in which an insulating conducting cylinder is placed with one end near to a conductor charged with electricity. He found by his insulating flame that a current of electricity was passing through the air space between the two conductors, and his explanation of the phenomenon is that a current is continually flowing along the line of conductors, which current is dammed back, as it were, by the greater resistance of the air, and appears as a charge of positive electricity at one end of the insulated cylinder. We have not been able to make any experiments to confirm Mr. Johnstone's statement as to the passage of electricity through the dielectric air, but at least in one of his deductions, namely, that the potential is greater at one end of the cylinder than at the other,

he is wrong. He may easily convince himself of this by connecting the opposite ends of the cylinder to the two poles of a quadrant electrometer.

We think that Mr. Johnstone is right in his view that there is only one kind of electricity, the so-called negative electricity being due to a diminution of the normal charge. Whether or not he is right in his view that electricity is matter, depends greatly on what definition of matter he adopts. It is impossible also, we think, to prove that he is wrong in supposing that, under certain conditions, electricity (if it is a substance) passes through the substance of a dielectric. All that is necessary, however, to support the modern theory of induction is, that during its passage it stores up the whole of its energy in an elastic dielectric in such a way that the dielectric has the power of restoring it more or less completely to the electricity during discharge. The controversy as to whether induction is real or imaginary, appears to us to resolve itself into a logomachy.

ELECTRICAL STANDARDS.

THE necessity for determining accurately the value of the electrical standards is growing day by day, and it seems time that energetic steps were adopted to have the matter taken in hand. The work of carrying out the determination is by no means easy, but so many practical suggestions have been put forward, and so many preliminary experiments made by various workers, that the chances of obtaining reliable results are vastly greater than they were a few years ago. Some time since, Lord Rayleigh advocated certain work which he considered necessary to be done before the conditions for an accurate determination of the value of the ohm could be advantageously discussed. This work, at least one of the papers read before the British Association, stated had been accomplished, and therefore, in view of the practical necessity for an authoritative determination having arisen in connection with the standardising laboratory, the author thought the time ripe for the whole matter to be dealt with. In view of the extreme importance of the subject, it seems reasonable that a Government grant should be obtained for the purpose, and this would, we believe, be largely supplemented by the free-will offerings and labour of those interested. In view of the fact that the adoption of a correct standard is an international matter, it is of great importance that the work be carried out in this country as thoroughly as possible, no expense being spared to effect the required object in a manner which shall disarm criticism. If this is not done, we shall be liable to have the results questioned by others who have been privately working, and who may claim that they have arrived at their determinations by methods and with apparatus equally efficient with those employed by our own scientists. In fact, we believe that it was some such argument as this which led to the absurdity known as the legal ohm, which, however, fortunately never came into actual use.

Waste in
Transformers.

SIR WILLIAM THOMSON'S B.A. paper on Anti-effective Copper in Conductors is not only of scientific interest, but has, in addition, great practical value. The author shows that though the ohmic resistance of a conductor may be reduced as its cross section is increased, a thickness is soon reached at which, notwithstanding the reduction of the ohmic resistance, an addition of copper causes an increase in the heat generated by an alternating current in the conductor. This results from an unequal distribution of the current throughout the cross section of the conductor which is caused by parasitic currents generated inductively in its mass. After a certain point, then, not only does increasing the copper fail to give an advantage, but it is productive of actual loss, or becomes, as Sir W. Thomson puts it, anti-effective. These considerations are specially applicable to the case of coils consisting of several layers of wire laid above each other in series, as in the various forms of transformers; but the author shows that a remedy for the evil indicated may be found in employing a stranded conductor which has its separate wires insulated from each other by a slight coating of varnish or other suitable material. In his paper on Alternate Currents in Parallel Conductors, Sir William Thomson considers the effective resistance offered by conductors to alternating currents or rapid discharges of electricity.

Permanent Magnets.

MR. PREECE'S interesting paper "On the Character of Steel used for Permanent Magnets," gives the results of a large number of experiments on magnet steel made at the Post Office. It will be seen from the figures that the French specimens are much superior to those supplied by English makers, as far as strength is concerned; at the same time it is possible that in the former the magnetism may be less permanent, and we believe we are correct in saying, that in instrument work, permanence is of quite as much importance as strength. We are pleased to note that Mr. Preece means to further investigate the matter, when the point to which we have referred will doubtless receive full attention.

Effect of Electricity on
the Human Body.

MESSRS. LAWRENCE AND HARRIES have supplemented their paper read before the Institution of Electrical Engineers, by one read at the B.A. meeting, in which further experiments are recorded. This time they used the currents from actual lighting circuits, and obtained results widely different from those given in their previous paper. The figures given in Table C, showing the variation in the strength of the current with the contact area, seem very extraordinary, and demand further elucidation. That there is a relation of some kind is undeniable, but from the readings it seems impossible to formulate any definite law respecting it. The paper and the conclusions at which its authors arrive are before our readers, who can, themselves, extract from it such information as they think may be of service. The main conclusions are that an alternating current of 100 volts sends through an ordinary individual, touching the poles with his hands, a current which produces muscular fixation, thus depriving him of the power to release himself, while by a direct current no such

effect is produced. The obvious moral is—Don't touch the poles at all, advice which most users of electricity will be pleased to take.

Electrical Exhibits
for 1893.

THE National Electric Light Association held its twelfth convention at Cape May and deliberated upon topics of common interest to the electrical fraternity. As usual, many of the questions under discussion were more or less of local importance, but those which may claim universal attention were by no means plentiful. Prof. John P. Barrett read a paper on "Electrical Industries and the World's Fair," setting forth the deficiencies in matters of electrical exhibits at the Paris Exhibition of 1889, and he exhorted his hearers to make the utmost effort for a gigantic display of American electrical machinery at the proposed great exhibition of 1893, to be held at Chicago. At the present time there are in the United States some 430 separate companies and individuals who may be expected to apply for space, but everyone of this number will probably defer action until the last possible moment, unless the importance of securing the necessary space and having the exhibit in readiness within the appointed time, is impressed upon them. Some of the manufacturers will have to be coaxed into making exhibits, while others will hesitate on account of the expense entailed. The author criticised the methods adopted at Paris and other exhibitions, and suggested that exhibits should be arranged according to the various types of apparatus, irrespective of the main display of the exhibitor. That is, to place all telephone apparatus and everything thereto appertaining in close proximity; the same with telegraphic apparatus, arc lighting dynamos, incandescent machines, motors, &c. The carrying out of such a plan will, of course, give two or more separate exhibits to each manufacturer, and thus entail additional expense, both in the matter of suitable furniture, and possibly in the matter of attendance; but all this additional outlay would be more than returned in the excellent results attained, and in the simplifying of the study of any particular type of apparatus. This suggestion has scarcely the merit of novelty; at English exhibitions, especially those of an engineering character, this method of grouping allied subjects has frequently been carried out as far as it was possible to do so.

Prevention of
Accidents from
Electric Currents.

"WHEN the development of electric currents, on a large scale and at small cost, first became possible by reason of recent discoveries, the question of the dangers to life and property attending their use was brought prominently before the public, just as the dangers attending the use of steam, of rapid locomotion on railroads, and of dynamite were brought to the attention of the world when these powerful agencies first left the experimental laboratory of the chemist or engineer to take their part in the ordinary labour and business of life." With these words Prof. Henry Morton opens a paper on "The Dangers of Electricity." He maintains that a much smaller number of people are killed or injured by high pressure boilers than by low pressure ones; the same relation has been found between dynamite and gunpowder, the former having largely reduced the proportion of accidents and injury as compared with the work done. Without these "dangerous" agencies

man would be reduced to the lowest condition of savagery, when he would be at all times helplessly at the mercy of the "elements," or the blind forces of nature. Referring to accidents from high tension currents, the author states that the "Employer's Liability Assurance Corporation" had collected a mass of material from a great variety of sources, and it has formulated a series of rules for the protection of those employed in erecting and operating electric apparatus involving the use of dangerous currents. These rules have been examined and approved by several prominent electric companies, and so far it would appear as if no accidents have resulted from the use of electric currents where these rules have been followed, and that most, if not all, the accidents which have occurred would have been prevented had these rules been obeyed.

Secondary Cells.

IN his concise paper before the British Association, Mr. Barber Starkey sets forth the history of his discovery of the effect of carbonate of soda upon the sulphate in lead sulphuric acid cells. We have repeatedly referred to this subject in our columns, and need only mention now the present statement of Mr. Barber Starkey, which is to the effect that according to his experience it is no longer necessary to pass a heavy current through cells to prevent sulphating, and he suggests that it would be more satisfactory to use larger cells than has hitherto been customary for stationary work, and both charge and discharge them at a considerably lower rate than at present recommended, thereby enormously increasing the life and efficiency of the cells, and leaving a large surplus in case of emergency. His own cells have been treated in this way, and they have not materially deteriorated after nearly five years' use. The author also recommends the use of soft lead grids in preference to those of a hard and brittle alloy. The desirability of this we were the first to point out some years ago, when lead-antimony grids came into fashion, giving substantial reasons for our assertions, and, we believe, the practice of using the latter has been abandoned by those who formerly advocated it. If it is desired to use separators between the plates, a very simple and cheap way to make them is to use perforated porous paper which has been saturated in melted paraffin wax, this, says the author, stands well in dilute acid, and he had some in use for several years. Referring to his method of preparing a solid electrolyte of plaster of Paris 1, sawdust $2\frac{1}{2}$, and dilute sulphuric acid until set into a compact porous mass, Mr. Barber Starkey relates that the cells filled in this manner and used on the Barking Road tramcars have apparently been a failure, although he had some success with this process in his own set of batteries. The defect of this arrangement would appear to be that it must hinder the free circulation of the liquid, and also add to the internal resistance of the cell, whilst, on the other hand, it prevents the plates from buckling, retains the active material firmly in its place, preserves the plates from injury and makes the cell very portable.

Determining Electric Motor Rates.

THERE are in the United States some 15,000 electric motors in use for almost every conceivable purpose, and the great majority of these are connected with central stations. One of the difficulties experienced by central

station managers was the charge that should be made to consumers for the use of electric energy. If all these motors were in constant use and giving off constant power, then it would be an easy matter to determine a fair rate for the current consumed, but few, if any, motors are doing constant work, some are at times much overloaded, others are never worked to their full capacity, and, as a rule, machinery in workshops must stand idle for considerable periods when work is being removed, prepared, or set in machine tools. Mr. H. L. Lufkin has made an accurate study of the conditions which obtain in various trades relatively to the average power consumed by machinery, and he has set forth the results in a series of diagrams illustrating the paper he read on this subject at the National Electric Light Convention. These diagrams illustrate the fluctuations in the current supplied to motors in actual practice, they give the maximum, minimum, and average readings, the current consumed in driving the shafting, and the peculiarity of the records of motors operating lifts. In some cases it is shown that over 60 per cent. of the average power developed by the motor is employed solely in overcoming the friction of shafting, where one large motor drives a number of machines. This would point to the advisability of using a number of smaller motors driving individual machines, and it is merely a question of relative efficiency between small and large motors. In a typical case of a 15 H.P. motor working lithographic presses the maximum rate consumed is 10 H.P. The user is given a 10 H.P. rate at \$60 per month, but the average power consumed is but 6.7 H.P., therefore he pays \$9 per H.P. per month instead of \$6 per H.P. for the power actually consumed. This difficulty, we think, could be easily overcome by attaching to each motor circuit a special meter. Meters of the ordinary kind for electric lighting are complicated and expensive, owing to the wide range they must have. Now a 70-ampère motor could never use less than 10 ampères, even if running an idle lathe or shafting, thus the extreme range would be about 1 to 7. Such meters could be made very cheaply and yet be perfectly accurate within such narrow limits; by this means both suppliers and consumers might be satisfied.

The West India Cables.

THE resuscitation of the scheme for a direct cable between Spain and Cuba, has given the Spanish technical press an opportunity of again inveighing against the concession granted in 1868, to the West India and Panama Telegraph Company, for a period of 40 years. This concession was given with the intention of making Cuba the centre of all the West India telegraph communications, the wording being to the effect that direct submarine telegraph lines should be laid between Cuba and Puerto Rico (two Spanish islands), and radiate from Cuba to Panama, to Mexico, and to South America. The telegraph company, however, instead of complying with the stipulations of the concession, laid a cable from Cuba to Jamaica, from Jamaica to Puerto Rico, from Jamaica to the isthmus of Panama, and connected up South America *via* the other West India islands, and in this manner declared the clauses of the concession fulfilled. The article from which we quote says:—"It is with shame that we must confess that this contempt of contract, this injury to national interests was consented to by the Spanish Administration." We are told that, not content with this infraction of the

most vital clauses of the concession, the telegraph company, jealous of its privilege, has taken every possible measure to prevent any other persons establishing a direct communication between Cuba and Puerto Rico. In view of the fact that the company has in no way fulfilled the stipulations of the contract, the concession must *ipso facto* become null and void, and it is the duty of the Spanish Government to further in every way the laying of a cable between Spain and Puerto Rico, and between Puerto Rico and Cuba.

B.A. Ethics.

JUDGING from several letters which have recently appeared in *Nature*, it seems that the time is not far distant when some radical changes will be made in British Association procedure. The points touched upon in these communications, however, do not stand alone, for a comparatively new departure in the ethics of "learned" bodies has recently been made, which, if further developed, will scarcely tend to raise the standard of associations sanctioning such questionable policy. Two at least of the papers read before the British Association meeting had previously appeared *in extenso* in one of the scientific journals, and naturally it often occurs that the same individual submits papers on a certain subject before two or more societies. As a rule, the author has good taste enough to vary the text, and to introduce into each some special point of interest not common to both. But to write an article in a journal, get the credit, if nothing else, and subsequently present this very same article in the form of an original paper to the B.A., indicates motives which Mr. S. A. Varley would characterise as of questionable morality. Considering the publicity which is given to the deliberations of the British Association, there is not even the excuse of a desire for self-advertisement, and we can only put down such conduct either to a want of originality on the part of the authors, or to an utter indifference to the object which brought the association into existence. Had the authors been small fry there is but little doubt that their contributions would have been tabooed, but in the same way as there is said to be one law for the rich and another for the poor, so it seems that science panders to the great at the expense of its more humble devotees.

The Latest Millionaire.

THERE is one means by which the B.A. meeting is rapidly bringing itself into world-wide notoriety, and which for several years past has been getting more and more ludicrous; we allude to the strange hallucinations under which Mr. W. H. Preece seems to labour and which give rise to those frequent utterances which at once make him the comic man of the party. In the daily press reports of Section G, last Tuesday, we noticed that Mr. Preece spoke of the extreme importance of preventing dangers to the public. During a lifetime associated with electricity, he believed he had experienced a *million shocks*. Small as were some currents, they possessed a certain amount of danger from shock or fright to the individual affected, and might perhaps cause stoppage of the action of the heart. Now, taking Mr. Preece's age as 56, a trifling calculation would apparently show that he has been receiving shocks, more or less severe, during all these long years at the rate of 50 per day, and yet he survives. But seeing that he did not enter the electrical profession until he was 18 years of age, and making

due allowance for Sundays and B.A. meetings, he has undergone muscular contractions during business hours at the rate of say, one in every five minutes, knocking out the decimals. The genial electrician of the Postal Telegraph made some further remarks upon skin resistance, and it is to be hoped that next year he will be able to place before the meeting a precise definition of both a thin and thick-skinned individual. We fear, however, that if he does not curb his too lively imagination, he will sooner or later receive a shock, not necessarily electric, which will seriously discount his remarkable gifts as a lecturer on science, even if it falls short of stopping the beating of his large heart.

Newspaper Techniques.

THAT the "Silly Season" has not yet come to an end, is evidenced by the correspondence in the *Daily Telegraph* on electric carriages, where the advisability of having private vehicles propelled by electricity is being as gravely discussed by people who know nothing whatever of the subject, as is that more complex matrimonial problem, originated by a recent breach of promise case, by those who apparently know still less. Let us first see electric tramlines commercially successful before troubling our heads with minor matters which can very well wait their turn until the time is ripe, if it ever comes, for dealing with them.

A Graceful Compliment.

PROF. OLIVER LODGE must have experienced a proper degree of pride during the past week. Not only was a paper of his, previously published, read at the B.A. meeting, but an admirable portrait of the author of "Modern Views of Electricity," which probably excited the envy of all his less-favoured compeers, appeared as a supplement in an esteemed contemporary, the price of which, in honour of the event, or more probably in the true interests of science, was raised 50 per cent.

Fire Risk Rules.

THE Phoenix Fire Office Rules have met with another rebuff at the hands of Mr. Wilson Hartnell, who, in his B.A. paper, recommends the adoption of those compiled by the Institution of Electrical Engineers. We hope soon to be able to devote special attention to this matter, the importance of which is shown by the completely opposite views taken on existing rules.

The Georgetown Telephone Exchange.

WE have received an interesting account of the opening of the new telephone exchange in Georgetown, British Guiana, which is arranged for 200 subscribers. The whole of the work, which commenced last December, has been carried out by Creole labour, superintended by the Government Electrician, Mr. Samuel Vyle, who may perhaps be remembered by readers of the REVIEW of some years' standing. From what we can gather, Mr. Vyle has made himself quite indispensable in his sphere of operations, and appears to have become immensely popular with the Georgetown community.

ELECTRIC LIGHT IN NEWSPAPER OFFICES.

THE advantages of the electric light are probably more fully to be found in the establishment of a daily newspaper than in most places, and the progress of the light in printing establishments throughout the country has become very marked. The latest installation of which we are aware is that at the offices of the *Manchester Examiner and Times*. This is an old-established paper, but it has of late changed hands, and the present proprietors have been making thorough changes with the view of enhancing their property, and one has been installing the electric light in the place of gas; gas, however, is highly valued in this establishment, for it is used with one of Crossley's largest sized engines for driving the various printing machinery.

The installation in its present form consists of over 200 incandescent lamps of 16 C.P., but a larger number will be shortly added. The entire work has been carried out by the Manchester Edison-Swan Company, Limited, which has done the principal electrical work in this district for many years.

The lamps are placed throughout the building from the printing and paper rooms, where there are 32 lights, to the top, where over 100 lights are placed in the composing room. The offices and publishing department on the ground floor, the editor's and other rooms, are fitted up and appear to have been arranged with the view to extra light and comfort. The dynamo is of the company's Lancashire type, having a capacity of 300 lights, at an E.M.F. of 100 volts, with 900 revolutions per minute. It, however, is arranged, in this case, to run at 600 revolutions per minute, giving an output of 220 to 230 lamps at 100 volts. The engine is a special vertical electric light engine, by Marshall, of Gainsborough, with double fly-wheels, complete, for this special work. The speed is 150 revolutions per minute. The boiler is of the locomotive type, also by Marshall, arranged with the flue drawing downwards, and specially arranged to suit the confined situation it has to work in. The engine has been so fixed and arranged that in case of any accident or breakdown to the gas engine, it can be coupled up to drive the printing plant and other machinery. The wire and cable used throughout the installation is of Glover's double rubber insulation, and the capacity of the copper is calculated on the basis of about 750 amperes per square inch. The cut-outs, switches and holders, are all of the Manchester Edison Company's own patent type. The fittings are generally of a plain description, most of the shades being 9 in. flat opal. The work has been well carried out by the staff of the company, under the able supervision of their manager, Mr. M. P. James Fawcus, A.I.C.E., to whom the credit of planning out the entire arrangement is due. The installation has been started running within the last few days, and is working very successfully.

COMMUNICATIONS FROM AUSTRIA-HUNGARY.

[FROM A CORRESPONDENT.]

AS I already announced to you on a former occasion, the town of Teplitz purposes erecting electric works for lighting up this celebrated watering place. The town has resolved not to renew the contract for street lighting with the gas-works (which expires on August 1st, 1891), but to erect an electric central station at its own expense, and to carry it on as a municipal electric works. Concerning the right of the town to annul the agreement with the gas company, there prevail different views, and it may probably lead to litigation between the town and the company. Meanwhile, the municipality has already applied for proposals to different firms, e.g., Siemens, Ganz, Schuckert, Egger, Krenetzký, and Waldock, jun., Wagner, without loss of

time. Several proposals have been already made to the town, both on the part of the gas company and of other contractors, applying for a concession for supplying an electric current. One undertaking even proposed to light up Teplitz, Aussig, and other towns of the district, from a common central station. The town, however, has declined all these offers, and has voted the sum of 300,000 florins for the erection of a municipal station.

Two localities, both within the town, had been proposed for the works. Subsequently it was judged better to erect the works outside the town, close to a coal-mine, so that the coal could be at once utilised on the spot without the cost of carriage. The coal-mine is about 600 metres distant from the town and about two kilometres from the most remote buildings to be lighted up. As the gas agreement expires on August 1st, and it cannot be expected that, in the case of its non-renewal, the gas company will further undertake the public lighting, the town must be prepared to have the electric works ready for action by that date.

A very interesting process between the city of Vienna and the Vienna Imperial Continental Gas Company has been just decided. The dispute did not refer to the carrying out of any definite claim, but formed a so-called "prejudicial accusation." The city wished to have a clear decision as to its future position with regard to the gas company, i.e., whether the company, after the expiry of its agreement, was entitled to leave the gas mains in the soil of the city—in other words, if the city, after such expiry, would be authorised to insist upon the removal of the gas mains. The Supreme Court decided that the Vienna Imperial Continental Gas Company, after the expiry of its agreement with the city, is bound to remove the mains and pipes from the ground. This decision holds good, of course, for undertakings for electric lighting with underground cables, and is, of course, very important. All such undertakings, in default of an express stipulation to the contrary, in virtue of the above decision, will be bound to remove their nets on the expiry of their agreements.

The Buda-Pest Tram-line Company (Siemens and Halske) has applied for a concession to lay down an electric tram-line on the right bank of the Danube, which subsequently, after completion of the fourth Danube bridge (recently projected), is to be joined to the net of electric tram-lines on the left bank. The new line is to terminate in a mountain line, and lead up to the celebrated Blocksberg, from which there is a splendid view of the city and its vicinity, and which, in the last few years, has become a very favourite resort of the public of Buda-Pest.

The Imperial Court management has resolved to provide all parts of the royal Hungarian castle, situated very picturesquely on the citadel, with electric lamps. If an electric installation is erected in Buda-Pest at an early date, these lamps are to be attached to the general net. If the execution of this project is too tedious, a special lighting station is to be erected for the castle, though outside its walls.

THE DANGERS OF ELECTRICITY.*

By Prof. HENRY MORTON.

WHEN the development of electric currents, on a large scale and at a small cost, first became possible by reason of the discoveries of Faraday, Wilde, Gramme, Siemens and others, the question of the dangers to life and property attending their use was brought prominently before the public, just as the dangers attending the use of steam, of rapid locomotion on railroads, and of dynamite were brought to the attention of the world when these powerful agencies first left the experimental

* A paper read before the American National Electric Light Association, August 20th, 1890.

laboratory of the chemist or engineer to take their part in the ordinary labour and business of life.

In each instance alike there was a class of people who took the narrow and partial view, that if an agency was dangerous it should be excluded altogether from public use, or, what amounted to the same thing, be surrounded with such exclusions and limitations as would rob it of nearly all its capacity for usefulness, and restrict all possibility of advance and development in its application.

Thus laws were actually passed in England on the first introduction of steam, limiting the pressure in boilers to 30 lbs. on the square inch.

The first railroad charter contained a clause limiting the speed of trains to 12 miles an hour, and when a speed of 30 miles was suggested, it was ridiculed in a prominent journal of the day as an idea simply insane, and it was said that people would just as soon be persuaded to allow themselves to be fired out of a cannon as to be hurled along at such fearful velocities, which would, without doubt, have the most disastrous effects upon the circulation of the blood and other vital actions.

Some of us can also recollect the excitement produced and echoed in the press on the introduction of dynamite, and the stringent laws regarding its transportation, which in many cases only increased the danger to the public by occasioning its surreptitious conveyance in passenger and ordinary baggage cars.

We shall have to be very young indeed not to remember the great popular excitement brought about by the daily press when electric lighting first appeared in the streets of New York, and when flashes of flame were described as proceeding from a horse that had run against an electric wire.

In all the older instances matters have settled themselves in accordance with the laws of human progress and the diffusion of intelligence, and we now have boilers running at pressures of 140 lbs. and upwards, trains going more than a mile a minute, and gunpowder largely superseded by dynamite.

What is more, the accidents and injuries actually produced by these several agencies have been vastly less than those caused by the things which they replaced.

A much smaller number of people are killed or injured by high pressure boilers than by low pressure ones. How rarely do we hear of the explosion of locomotive boilers, which usually carry 140 pounds pressure.

The accidents to express trains are as nothing compared to those occurring with freight trains, and the loss of life and injury to passengers by rail is insignificant in its percentage to the number carried, when compared to similar loss and injury incurred in the days of stage coaches.

The same relation has been found between dynamite and gunpowder, the former having largely reduced the proportion of accidents and injuries as compared with the work done.

Two lessons are very plainly taught by the facts of history above alluded to.

First: The world is not going to be frightened away from a new and valuable source of power by the circumstance inseparable from the very nature of all powerful agencies, that it is dangerous if not adequately controlled; but, on the contrary, will develop the new power to an ever-increasing and, therefore, more (possibly) dangerous intensity.

Second: Intelligently managed and controlled, the most powerful and, therefore, in a sense, dangerous agencies, become the most efficient protectors and servants of man, and not only aid him in his mission of subduing and utilising nature, but actually protect him in his work.

Without these "dangerous" agencies man would be reduced to the lowest condition of savagery, where he would be at all times helplessly at the mercy of the "elements," or the blind forces of nature.

With them he not only defies and subdues the beasts which would otherwise be his superiors, but even conquers and renders tributary to his comfort and advance-

ment those vast forces which control the entire matter of the universe.

Applying these lessons taught by the past history of the world in parallel cases to the problem of the distribution and use of electricity, we see, in the first place that the way to deal with its dangers ought not to be the timid, obsolete way of prohibition, or of unintelligent restriction, such as that which proposed the exclusion of locomotives from railroads, or the limiting of their speed to 12 miles an hour, but the sensible way of providing adequate safeguards to the new power, and with these allowing it to follow its natural line of development and growth into higher and higher ranges of intensity and consequent efficiency.

It is too well known to all to need statement, that the methods thus pointed out by history and taught by experience have not been by any means universally advocated or followed, and that while many have loudly demanded the exclusion of powerful electric currents, the limitation of their intensity to what they suppose to be necessarily harmless ranges, the users of such electric currents have in too many cases neglected the most obvious precautions.

It is only fair to say, in explanation of this latter statement, that this neglect has in many cases been brought about by obstructions thrown in the way of good work by those who were exciting themselves for the total abolition of dangerous currents, and who, like certain "total abstinence" advocates, objected to every mitigation of the evil they attacked, because any such improvement weakened their case against it.

As regards dangers to property from fires, the matter fortunately fell at an early period into the hands of the Board of Fire Underwriters, who, in a judicious and business-like way, investigated the subject and formulated such rules as have proved eminently satisfactory, and have proved that under proper regulations as to good work and means of protection, electricity is by far the safest means known to us for the distributing and development of light, so far as "fire risks" are concerned.

In view of the satisfactory results thus obtained, I regard it as a fortunate circumstance that the other part of the problem, namely, that relating to dangers to human life, has been recently taken in hand by a similar organisation known as the "Employer's Liability Assurance Corporation."

This association, after collecting a mass of material from a great variety of sources, has some time since formulated a series of rules for the protection of those employed in erecting and operating electric apparatus involving the use of powerful, and, therefore, dangerous currents. These rules have been examined and approved by several of the managers of prominent electric companies, and, so far, it would appear as if no accidents have resulted from the use of electric currents where these rules have been followed, and that most, if not all, the accidents which have occurred would have been prevented had these rules been followed and obeyed.

Having had something to do with the framing of these rules, it is my chief object in presenting the present paper to secure their criticism by those bestable to perceive their imperfections, and such suggestions as may lead to their beneficial modification or extension.

I therefore quote them as follows:—

First. Do not touch or handle any electric wire or apparatus of any sort while standing on the ground, or while in contact with any iron work, gas or water pipe, or stone or brick work, unless your hands are covered with rubber gloves, and you are provided with such properly insulated tools as have been declared to be safe and in good order by the electrician or other competent officer of this company.

If it is at any time necessary to stand on the ground, or on any surface not insulated from the ground, while handling electric wires and apparatus, rubber boots or an insulated stool should be used.

In moving wires, hanging on, or lying over, electric light wires, lamps or fixtures, use a dry hand line,

Second. Never handle any electric wire or apparatus with both hands at once when this can be avoided, and, if it is necessary to do so, be sure that no current is present, or that one or both hands are protected by rubber gloves or other efficient insulation.

Third. When handling line wires, treat each and every wire as if it carried a dangerous current, and under no circumstances allow yourself to make contact between two or more wires at the same time.

Fourth. Never open a circuit which has been in use without giving notice to the superintendent, or whoever is in charge, of your intention to do so, and at the same time request that the same line be opened at the main station, and kept open until you have given notice that your work on that line is complete.

Fifth. In the dynamo room never go near the belts or dynamos, nor touch any apparatus unless you are fully informed and instructed how to do so.

Tools used by linemen should be provided with insulating handles of hard rubber or other equally good insulator. It is the duty of each lineman to look after his own tools and see that they are in good order, especially as to their insulation.

Sixth. Lamp trimmers and others engaged in the care of lamps must see that the switch putting the lamp in circuit is turned off before they handle the lamp in any way.

Seventh. In construction work, a space of at least 20 inches must be left between the holes for pins on the cross arms, so that a lineman may get to the top of the pole and work without danger.

The same insurance association has collected the authentic records of a number of so-called "electric accidents" or accidents happening to the *employés* of electric companies. I have now before me the abstracts of 91 such cases.

The first thing that presents itself in looking over this set of abstracts is that very few of the accidents are in any way attributed to electricity directly, but would have occurred had the establishment in question been any kind of a factory where power was being used, or any place where heavy objects were being moved. A few examples will illustrate this, thus:

"No. 1. Whilst steadying with a pike-pole a large electric light pole which was being placed in position, a passing 'low-gear' belonging to the Standard Oil Company ran over ankle."

"No. 2. While assisting in hoisting a stick of lumber from the street to the second floor of electric station, was injured in right foot by having the stick fall upon it."

"No. 9. Was going to dynamo, stepped on iron plate temporarily covering a belt hole in floor. The plate tipped and he fell partly through the opening, injuring himself internally."

"No. 17. Was oiling rocker shaft of engine near fly-wheel; leaned back too far and was struck on head by spider of fly-wheel."

The above are fair samples of the rest, and, in fact, out of the 91 cases but 15 (or about 16½ per cent.) have any direct relation to electricity.

As I have already mentioned, of the 15 cases in which the injury was in any way caused by electricity there are none in which the action would not have been avoided if the above quoted rules had been observed. Thus, beginning with first in order as arranged in the abstracts, all before it having no direct connection with electricity, we have:

"No. 11. While removing the wire from a Brush dial or regulator which had become short-circuited, was slightly burned on two fingers of right hand."

In this case the beneficial effect of rule No. 2 was manifestly expressed, and had the spirit of rule 7 been complied with even the slight injury experienced would have been avoided.

The next in order is:

"No. 20. Was putting carbon in electric lamp which was out of order and failed to burn. Received charge of electricity, which caused him to fall down from step-ladder on to steam radiator. Two ribs broken."

This would clearly have been avoided by an observance of rule 7.

Time will not permit me to quote all the 15 cases, and I will, therefore, only repeat that they would, all of them, have been avoided by a strict observance in form and spirit of the above quoted seven rules or directions.

Of course I do not mean to imply by this that these rules are perfect or complete, but only that they seem to be in the right direction, and to furnish a starting point from which further developments may proceed.

No one having even an elementary knowledge of electricity as it existed 10 years ago, needed or needs to be convinced of its power to do harm where all safeguards are removed, and the occasional declarations of its harmless character which have been uttered can only be accounted for by reference to that combative disposition which impels some minds always to take a view in opposition to any which may be expressed, and gives birth now and then to a book or pamphlet disproving the law of gravitation or the solar origin of light and heat. To say this is, however, far from agreeing with the other extremists who would banish electricity from our daily walks and occupations, or place it under restrictions which *might* render it harmless, but which *certainly would* render it relatively useless for the countless purposes in which its efficiency demands its full development.

The true opinion is that which is supported by past experience, and which advocates the fullest developments of power to which this agency can attain, combined with the use of all the means of protection by which human intelligence can protect itself while using to the utmost this potent and, therefore, dangerous weapon in our victorious contest with the inimically destructive forces of nature.

UNDERGROUND CONDUCTORS IN MADRID.

THE *Ciencia Electrica* of Madrid, is publishing a series of articles, written by Senor J. Casas Barbosa, formerly the manager of the Sociedad Matritense de Electricidad, under the title of "Electricity in Spain." The electric lighting of Madrid naturally claims precedence, and the articles in question deal, for the present, with the operations, in that city, of the company above-mentioned. Especial mention is made of the installations in the gardens of Buen Retiro and in the park of Buenavista, including, in the latter, the illumination of the Ministry of War.

In reviewing the results of the distribution of current by means of overhead wires, the conclusion is arrived at that this method is altogether unsatisfactory, experience showing that it is untrustworthy, precarious, and only suitable for purely temporary necessities.

In view of the uncertain nature of overhead lines, the Sociedad Matritense turned its attention to the question of canalisation and underground conductors.

Many difficulties were encountered in realising the proposed change, among them being the exclusive authority over the public roads assumed by the gas company, and which had been tacitly assented to by the authorities and the public, though unsupported legally.

In the year 1883, Senores Dalman and Losada obtained the right of canalisation over a considerable area, but the experiment was actually extended to only the very limited distance of about 2 kilometres. The system consisted of a conduit of Portland cement, containing two parallel semi-circular troughs. The conduit was covered in with blocks of cement. Wires covered with tarred tape were laid down, but on account of the damage caused to this covering by haulage and the frequent presence of water in the conduits, the system failed completely.

By degrees the tape-covered wires were replaced by others covered with impregnated yarns and enveloped with lead, but the porosity of the metal caused frequent disasters, although, in some cases, the experiment

was tried of placing a double covering of lead over the wires.

In 1886 the condition of the cables had become so bad that it became necessary to attempt some further remedy. Pieces of wood impregnated with tar were placed at short intervals along the conduit. The wood was shaped to fit the semi-circular troughs, and on the upper edge slots were cut to receive the cables, which were thus suspended clear of the sides and bottom of the troughs. After six months' service it was found that excessive leakage prevailed over the system, and on examination it was discovered that an electrolytic action had been set up at every point where the cable was supported by the wood. These pieces of wood were consequently replaced by well-lacquered porcelain supports, which have given very much better results.

The author considers that a lead covering to the cables frequently constitutes a serious danger, and he goes on to say that, in his opinion, a bare copper bar, suspended by means of insulators from the arch of a conduit, presents the best method of insulating an underground conductor. At the same time, the case is quoted of the Barcelona installation, where bare copper bars were placed underground in the manner above indicated. The system signally failed, owing to the presence of water in the conduits.

the travelling over a slack rope would prove more interesting and attractive to the general public than a rigid rail.

Telpherage has taken some years to bring to its present perfection, but during that time the difficulties, which have naturally arisen in an undertaking of such a character, have been successfully met, and the particulars now made public seem to be convincing of the simplicity and reliability of this, the most modern method of transport.

The system comprises arrangements for the transport of a wide range of material, from minerals and heavy freight to light packages, the lines being constructed for the particular purposes for which they are required. These lines partake of the same general character, the practical effect being an overhead line, with carriers specially suited for the employment of electricity in the transmission of the power required.

The Edinburgh line consists of over a quarter mile of track, the flexible portion of it being constructed in spans of 50 feet, and the rigid ends in spans of 15 feet. The stand ropes on which the locomotive and carriages travel are of crucible steel, and $1\frac{1}{2}$ inches in diameter. These are tightened, so that with a full load on the line there is a sag of about 2 feet $4\frac{1}{2}$ inches on the spans covered by the train.

The arms supporting the stand rope are arranged so that they move in either direction, allowing the sag in



We would also point out that in an earlier portion of the article the author refers to the installations at the club "Union Mercantil," and at the theatre "Romea," where the conductors, underground cables covered with India-rubber, have given exceptional satisfaction, the lengths of circuits being, altogether, about 16 kilometres.

In view of the extensive experience which Senor Casas Barbosa apparently has had with different systems under various conditions, his opinion as to the efficiency of bare copper rods deserves some measure of attention on the part of those engaged in laying underground electric light wires. We may add that the climate of Madrid is, generally speaking, very dry, with extremes of heat and cold.

CHEAP TRANSPORT.

THE Electrical Engineering Corporation of London and West Drayton, since securing the sole rights for the Telpher system of cheap transport, have been vigorously developing the system, and determined to put up a Telpher line on a practical scale at the Edinburgh Exhibition to show the most recent improvements, and to so arrange the line as to carry passengers, and demonstrate the advantages of the system for the transport of goods. As a rule, they recommend rigid lines for the carriage of passengers, but it was thought that

the rope to follow the train as it moves along, thus obviating any undue strain upon the posts themselves. The stand rope at its junction with the rigid rail passes from a special descent junction saddle, so arranged that the train rises from the rope on to the rigid rail without any jerk or other unsatisfactory movement. From the junction saddle it passes direct to a structure termed the abutment post; this is fastened to the substantial anchorages in the ground by flexible steel ropes 5 inches in circumference. The strain upon the ends of the stand rope with a fully-loaded train is about 5 tons, and the strain upon the anchorages about 8 tons.

The current is conducted along a conductor, which is not attached to the insulators on which it rests at any point, but merely rests upon them. From the locomotive a rigid arm projects underneath the conductor, but above the insulators, and slides along under the conductor, lifting it off the insulators as the arm passes them, allowing it to rest on them again after it has passed. This method of collection, which is recommended in the "Waller-Manville" system of electrical traction, is proving admirably satisfactory.

The train, as will be seen from the illustration, is a very practicable one; the cars, which with the plant and the rest of the equipment were made at the works of the Electrical Engineering Corporation at West Drayton, are built much in the fashion of railway carriages, each car having two compartments and holding four persons, and each compartment being entered from a door with a railway latch. The space

in the cars between the passengers is the same as is allotted on the District Railway in their second class coaches. The whole of the car is suspended by iron hangers from two bogie trucks, the bodies of which latter consist of iron castings resting on the axles of the wheels at each end, and the hanger does not depend directly from the body of the bogie truck, but rests upon two vertical springs contained in boxes on each side of the body.

The locomotive consists of what is termed by the corporation a swinging tub, and the motor drives a small countershaft, to one end of which is attached an electrical governor to maintain a set speed; the other end of the countershaft has upon it a chain wheel which drives directly upon a larger chain wheel contained on the upper frame. The motor is suspended from the upper frame by a hanger, so arranged as to allow the whole to swing, the swinging movement thus allowed not interfering with the motion of the chain, as it is a movement radially to the centre of the large chain wheel on the upper frame. The upper frame contains, in addition to the large chain wheel, two driving wheels with malleable cast iron tyres to grip the rope, each attached to a chain wheel driven from the shaft supporting a large central train wheel.

The working of the line has, up to the present time, given every satisfaction, and has elicited considerable attention.

SPAIN AND MOROCCO CABLES.

THE *Ciencia Electrica* of Madrid, publishes an article upon the long felt want of some speedy and trustworthy means of communication between Spain and her possessions on the northern coast of Africa, and cites as an instance of this necessity, the recent troubles at Melilla, a Spanish fortress and convict settlement on the Riff coast of Morocco.

It is pointed out that as a first step towards protecting Spanish interests in Morocco, the example should be followed of the English, who have laid a cable between Gibraltar and Tangiers. This step is all the more necessary, in view of the attacks so frequently made on the Spanish outposts, by uncontrolled tribes, there being no telegraphic communication between the various military stations, or with the Peninsula. Considering the urgency of the case, the cost of the proposed cables, though assuredly a considerable item, ought not to be looked upon as an insuperable difficulty.

The Royal Decree of August 14th, inviting tenders, contains full details of the scheme, and particularises the proposed lengths of cables, as follow:

	Shore end.	Heavy intermediate.	Inter-mediate.	Light intermediate.	Deep sea.	Totals.
Tarifa-Tangiers ...	6.0	10.0	6.0	8.80	...	= 30.80
Tarifa-Ceuta	6.0	12.0	4.0	...	...	= 22.00
Almeria-Alboran....	6.0	20.0	6.0	15.0	36.60	= 83.60
Alboran-Melilla....	6.0	10.0	6.0	10.0	18.80	= 52.80
Melilla-Chafarinas	6.0	6.0	9.0	8.15	...	= 29.15
Melilla-Alhucemas	7.0	20.0	6.0	15.0	36.60	= 84.60
Alhucemas - Peñón de Vélez	6.0	10.0	6.0	8.80	...	= 30.80
Totals.—N.M. =	43.0	90.0	43.0	65.75	92.0	= 333.75

With the exception of Tangiers, the proposed cables connect up no points of commercial importance, their *raison d'être* being purely political, and the attention now paid to the Morocco question is significant of a more active policy on the part of Spain. Fear of the results of French enterprise and influence, always a thorn in the side where Africa is concerned, has no doubt assisted towards the inauguration of a more determined course with regard to Morocco.

NOTES.

Burton Backward.—At a recent meeting of the Burton-on-Trent Town Council, the Gas Committee reported the receipt of the Parliamentary Electric Lighting Order, but added that they had as yet taken no further steps in the matter.

The Electric Light at Huddersfield.—At the last monthly meeting of the Huddersfield Town Council, it was reported that the sub-committee had considered the advisability of taking steps for establishing an electric lighting station, under the provisional order which the corporation had obtained, and had appointed the mayor, the chairman, the vice-chairman of the sub-committee, and Mr. Calvert to inspect the electric light systems in operation in other towns and to report thereon.

Palace Lighting.—The Emperor of Austria has decided that the electric light shall be introduced into his palace in Vienna, the Hofburg, where till now wax lights have generally been employed for the purpose of illumination. About 8,000 incandescent lamps will be required to light the building throughout.

Execution by Electricity.—A telegram from New York dated the 11th inst., reads:—"The writ of habeas corpus in the case of the Japanese Shubuya Jugiro, who was convicted of murder, and sentenced to be executed by electricity, has been refused. The counsel who resisted Kemmler's execution presented a writ declaring that the condemned man would be carbonised and tortured to death. The judge, in dismissing the writ, alluded to the sentence carried out on Kemmler which, he said, the United States Supreme Court had decided was legal."

Telephonic Communication between London and Paris.—The Hythe Town Council, on Wednesday, granted permission to the Postmaster-General to erect posts and wires in the borough.

The Electric Light at Lewes.—At a recent meeting of the local town council, the question of electric lighting was discussed. Mr. Farncombe, comparing the advantages of gas and electric lighting, said the Gölcher (New) Electric Light and Power Company, as notified in last week's REVIEW, proposed to give 240 lamps of 16 candle-power, and to light seven and a half miles of streets, at a total annual cost of about £600, as against £800 now paid for the 200 odd gas lamps. He believed the present gas mains only extended over about five miles and a half. If the council erected the plant themselves and capitalised the cost in the usual way, the total yearly expense of the electric light would be about the same as now paid for gas, while in the course of time the whole of the plant would belong to them and there would only remain the cost of maintenance. Men who had studied the subject, declared that where electricity had been introduced the gas companies had done better business than before. The contrast between electricity and gas was so striking that the gas consumers was compelled to go in for improved burners and more gas lights, consequently they burnt more gas. Several of the largest ratepayers in Lewes strongly urged that the electric light should be adopted. He saw a good many people, and he had not heard a single word against it. The corporation owned three sites that were available for the machinery to produce the electric light, and he was informed that their situation was admirably adapted for the suggested change. Further consideration of the matter was adjourned.

A strong opinion exists in favour of the adoption of the electric light, and it is understood that a public meeting will be convened by the mayor shortly, to go into the subject. Several of the borough officials, including the Medical Officer of Health, are in favour of improved lighting, while one large ratepayer has already expressed his desire to have the electric light laid on to his house.

The Electric Light at Bristol.—The Sub-Electric Lighting Committee appointed to visit certain parts of the country in search of information, has now reported to the General Committee. The last town visited was Bradford, in Yorkshire, where the corporation owns both the gas and the electric light, but only uses the latter for private lighting. The sub-committee recommends that the corporation shall take the electric lighting into its own hands, and that from 60 to 70 1,000 candle-power arc lamps should be erected in the main streets of the area comprised between Temple Meads and the Victoria Rooms, and College Green and Old Market Street.

The Electric Light at Winchester.—A short time since the corporation of Winchester advertised for tenders to light that city by electricity. Strangely enough, no reply has yet been received to the invitation.

The Electric Light at Derby.—At a recent meeting of the Town Council the Mayor proposed that a permanent committee, to be called the Electric Lighting Committee, be appointed until November next, and also annually on the 9th of November each year, with power to consider the provisions of the Electric Lighting Order, and to make such arrangements as the council might deem expedient. He further moved that it be a special order that the Electric Lighting Committee should consist of 11 members of the council, and the Mayor for the time being *ex officio*. The proposals were agreed to.

The Electric Light at Nelson.—The Nelson Gas Committee has instructed the gas manager to take the preliminary steps for permanently illuminating the principal streets of the town by electricity.

The Electric Light at Dundee.—At the last monthly meeting of the Dundee Gas Commission a statement was submitted showing that during the past four months the amount of gas delivered in Dundee was 65,976,700 cubic feet, being an increase of 9,656,400 cubic feet on the consumption last year. Mr. Henry Robertson stated that with a steadily increasing consumption of gas the board were apt to remain quiescent in regard to electric lighting; but he reminded them that there were at present a score of public works supplied with the electric light. Those who were supplied with the electric light were delighted with it. A letter from the Electric Installation and Maintenance Company, Limited, tendering its services for the construction and maintenance of electric works in Dundee was allowed to lie on the table.

The Electric Light at Fareham.—An experimental installation of the electric light for the illumination of the Fareham streets was made on last Friday night, over a portion of the system, by the Fareham Electric Light Company, the experiment being regarded as very satisfactory. The system adopted is the Thomson-Houston, and the currents are supplied from two dynamos located close to the steam flour mills. The Local Board has engaged to pay £500 per annum for the lighting.

Private Electric Lighting.—The residence of Mr. Matthew Stevenson, of Harrogate, has been recently fitted with a complete installation of incandescent lighting. The wiring and fitting were entrusted to Mr. E. C. Wallis, of Bond Place, Leeds. As this is the first private installation in Harrogate, no effort has been spared to make it successful.

Ship Lighting.—The R.M.S. *Dunnottar Castle*, the largest vessel in Messrs. Donald Currie & Co.'s fleet, made her trial trip on the Clyde last week. All modern improvements, tending to the safety and comfort of passengers, have been adopted, including an excellent electric light installation by Messrs. Siemens Brothers.

Electricity v. Gas.—A lengthy controversy over this subject, in connection with Fareham lighting, is taking place in the *Portsmouth Times*.

Nothing to Fear.—At the annual general meeting of the Sunderland Gas Company, recently held in Newcastle, the chairman said that for some years past he had made references to the electric light, but now he had nothing to say, as there was nothing to be dreaded.

Aberdeen Hammermen's Exhibition.—A recent addition to the attractions of this exhibition is a powerful search light, erected by Messrs. Macwhirter, Ferguson and Co., electricians, Aberdeen. The light is a naval projector, manufactured by Messrs. Crompton & Co., Chelmsford, having a 24-inch parabolic mirror and arc lamp for concentrating the beam, and is equal to from between 20,000 and 30,000 candles.

Business Extension.—Messrs. Elliott Brothers, the well-known electrical, optical, &c., instrument makers, of St. Martin's Lane, having found it necessary, owing chiefly to the large increase in the volume of their business to greatly add to their premises, are making a large addition to their existing works. The building, which is quite a feature in the new street leading from Charing Cross to New Oxford Street, has a handsome façade of fine Dorset stone, and is characteristically named "Faraday" House. The back of the new building abuts on the back of the old premises which face St. Martin's Lane, the whole occupying a space of about 10,000 square feet. Although most of the space occupied by the new building will be employed as workshops, &c., by Messrs. Elliott, a portion fronting on the new street is to be occupied by "The Electrical Standardising, Testing, and Training Institution." The success of the firm, which has such a world-wide reputation, is a matter for congratulation, and is well deserved.

Edinburgh International Exhibition.—The East of Scotland Engineering Association held a special session at the Exhibition on August 5th and 6th. Amongst the papers read was one on the "Protection of Buildings from Lightning," by A. R. Bennett, Vice-President of the Association, in which the effects of several recent storms in Scotland on buildings and telegraph wires were described; and one descriptive of the telephonic exhibits, by C. G. Wright, Fellow. The remaining papers dealt with the mechanical exhibits, the one by Prof. Elliot, on the Locomotive Annexe, being specially noteworthy.

The Telephone in Great Britain.—The Central News says the expiration of the telephone patents in England will begin on the 9th of December next, and the monopoly will soon cease, and the *Sheffield Daily Telegraph* observes that, "so far, it has hardly been possible to purchase a telephone at any price, the only way to procure one being by paying a rental of £15 to £30 a year. We understand that Mr. A. Erskine Muirhead, of Glasgow, has been urging the telephone company to adopt the 'Ader' or 'Berthon' telephone, which at this moment enables people over 600 miles apart to speak with ease. Mr. Muirhead has demonstrated the practicability of telephonically connecting the towns of Great Britain by means of existing railway wires, and with the help of Van Rysselberghe's system. There is thus nothing wanting but comparatively inexpensive apparatus to enable, say, London to converse by telephone with Birmingham, or Bristol, or Aberdeen, at the same moment as telegraphic messages are being sent over the same wires. This practice has been in operation in Belgium and France since 1882. As is well known, people can telephone from Brussels to Marseilles, *via* Paris."

Notice of Removal.—Messrs. C. E. G. Gilbert and Co. have removed to No. 16, Hanway Street, Oxford Street, W.

Electric Welding.—*The Practical Engineer* concludes an article on Sir Frederick Bramwell's paper as follows:—"So far the applications have been to work not in competition with ordinary welding smith work, and we are of opinion that electric welders will not compete with ordinary work, as they are entirely inapplicable to the great mass of forge work, and the expense of use puts them outside of applications other than special and peculiar." We congratulate our contemporary on being so plain spoken.

The "Peral."—If certain of the Madrid journals are to be believed, it would seem that the submarine boat *Peral* has not turned out a failure after all. We are told that the reason for not building any more vessels after the pattern of the *Peral* is because one of the secret contrivances, appertaining to the submerging mechanism, has been made public by an English journal, while Spaniards were kept in ignorance of all details connected with the invention. The periodical we quote from goes on to say that, so long as six out of the seven especial inventions comprised in the mechanism of the *Peral* remain secret, there is nothing much to lament over, and the Government is adopting a proper measure of reserve in abstaining from further construction until the day when, Spain being at war, these powerful engines of destruction can be made use of against an enemy as novel weapons of offence.

The Compound-Winding Case.—The reason why the appeal to the House of Lords has been made may be seen by referring to the report of the Brush Electrical Engineering Company's first annual meeting. Those who have paid royalties for the use of compound-winding will doubtless feel flattered at the consideration which the company deigns to give them, more especially as nothing is recoverable should the appeal be dismissed. But surely, if the statement made by the chairman at the end of his last speech is correct, the manufacturers who have hitherto paid royalties can refuse to do so any longer, even if the company is successful in the House of Lords, on the ground that their dealings were with a previous corporation?

Railway Telegraph Engineers.—The Society of Railway Telegraph Engineers is to hold session in the Edinburgh Exhibition on the 16th and 17th of this month. The society is composed of the telegraph superintendents of the different railways. Two important exhibits, illustrating the telegraph, the signalling, and the block systems of two of the leading railway companies, will prove of special interest.

The Electro-Magnet.—The Journal of the Society of Arts for September 5th contains the first of the Cantor Lectures by Prof. Silvanus Thompson, D.Sc., B.A., M.I.E.E., delivered January 20th, 1890. The subject treated of is "The Electro-Magnet," and the inventions of Sturgeon, Henry, Roberts, and Joule are described.

Proposed Electric Tram at Hastings.—At the last monthly meeting of the Town Council a communication was received from Mr. J. Lees, enquiring whether the Council would entertain a project for a single line electric tramway south of the present parade rails from a point nearly opposite the Palace Hotel and the South Colonnade. The matter was referred to the Council in committee.

A Well-Known Fact.—A facetious friend, who noticed that in some of the B.A. papers attributed to certain authors, the mathematical portions were eschewed during the reading, suggests that the tendency on these occasions is merely to general lies. There is nothing new in this.

Electric Traction in Italy.—In the course of a few days the electric tram service between Florence and Fiesole will be open to the public. The preliminary trials have been highly satisfactory.

Electricity in Artillery Practice.—*Engineering* last week reproduced a very complete description, from the *Revue d'Artillerie*, of Paris, of the Canet system of quick-firing guns, which are equipped with electrical devices for training both in elevation and direction. If we are not much mistaken, the same ideas were carried out some years ago by Mr. Maxim, Mr. Crompton, and others, and although perhaps never put into practical operation, they were experimentally successful.

Cable Ships.—The ss. *Westmeath* arrived at her moorings off Messrs. Henley's Telegraph Works at Woolwich on the 8th inst. She is about to load cable for the extension of the Société Française des Télégraphes Sousmarins system in the West Indies. We believe the first section to be laid on this expedition will connect the French Island of Martinique with the town of Paramaribo, in Dutch Guiana. She is expected to leave the river early in October.

The ss. *Silvertown* came to her moorings off the Silvertown Company's Works on the 10th inst. She will take in cable for the West Coast of South America, the Central and South American Telegraph Company having resolved to continue their system southwards, from Lima, the capital of Peru, to Valparaíso, the chief port of Chili, touching *en route* at Iquique, the nitrate port, only. This extension of the Central and South American Company's cables would appear to threaten a serious rivalry to the existing lines along the coast, owned by the West Coast of America Telegraph Company. The *Silvertown* is expected to leave the river about the middle of October.

The Aluminium Company.—At the annual ordinary general meeting, held on Tuesday, at Cannon Street Hotel, Mr. Gerald Balfour, M.P., the chairman, said, amongst other things, that when the company was formed, it was expected the discoveries of Mr. Webster and of Mr. Castner, two of the vendors, now upon the board, would enable the price to be reduced from 60s. to 20s. But all their calculations were overthrown by the invention of an electric process for the production of the metal, which brought the cost down to 6s. or 8s. But he was glad to say that, though the metal could not be produced at a lower cost by their present process, yet Mr. Castner and Mr. Webster had discovered new processes of making aluminium and sodium, which, it was hoped, would once more enable them to compete with the electric process as far as the production of aluminium was concerned; while they would, it was hoped, also have a large sale for sodium.

New Zealand and the Cable Rates.—The New Zealand Government declines to bear a share of the subsidies and guarantees required by the cable companies in connection with the proposed reduction of the telegraph rates between Australasia and Great Britain, owing to the refusal of the Imperial Government to bear any portion of the responsibility.

Fatal Gas Explosion.—Yesterday forenoon a serious gas explosion, attributed to a leakage from a gas engine, occurred at the electro-plate works of Mr. C. H. Worsnop, in Cheapside, Halifax. The explosion almost brought down the building and set it on fire. A young man, named John E. Worsnop, was buried in the debris and has not been found, and a young woman, named Hartley, a burnisher, was killed, whilst a labourer was so seriously hurt that he lies in the infirmary in a precarious state.

NEW COMPANIES REGISTERED.

Railway Construction and Maintenance Company of Mexico, Limited.—Capital, £100,000, in £10 shares. Objects: To construct, maintain, and work railways, tramways, gas and electric lighting works, telegraphs, telephones, or other works. Signatories (with 1 share

each): C. Chabot, Romford, Essex; W. J. Longhurst, 20, Abchurch Lane; R. J. Garwood, 354, York Road, Wandsworth; G. Mannaford, Hendon; H. M. Winears, 15, Crosfield Road, South Hampstead; A. J. Kent, 8, Cross Road, South Wimbledon. The signatories are to appoint the first directors. Qualification: £500 in shares or stock; the company in general meeting will determine remuneration. Registered, 3rd inst., by Messrs. Bircham & Co., 50, Old Broad Street.

John Smith and Sons, Limited.—Capital £250,000, in £100 shares. Objects: To acquire the business of wool combers and worsted spinners, carried on by John Smith and Sons, at Field Head Mills, Bradford; to generate electricity, and apply the same for purposes of lighting, or as a motive power; and to supply electric light to any persons willing to purchase, rent, or use the same. Signatories: J. W. Smith, Mrs. Sarah Smith, B. Smith, John Smith, *J. White, F. White, 1 share each; *Isaac Smith, 10 shares; all of Bradford. The signatories denoted by an asterisk are the first directors. The company in general meeting will determine remuneration. Registered 4th inst. by Mr. C. Double, 14, Serjeant's Inn, Fleet Street.

London and Western Syndicate, Limited.—Capital, £10,000, in £1 shares. Objects: To search, prospect and explore countries, districts and places in America, Canada and elsewhere for the discovery of openings for the profitable employment of capital, and to execute and carry out public works of all kinds, including gas, electric light, telephonic, telegraphic and automatic power and other works. Signatories (with 1 share each): N. P. M. Tronson, 8, Drapers' Gardens; B. F. Weeks, 16, St. Helen's Place; R. Leapmann, 124, St. Vincent Street, Glasgow; F. H. Homan, 8, Drapers' Gardens; P. J. Economides, 79, St. Helen's Gardens, W.; G. Allan, M.I.C.E., 10, Austin Friars; W. Curtis Thomson, 10, Throgmorton Avenue. Registered, 8th inst., without special articles, by Robinson & Stannard, 17, Eastcheap.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

General Electric Company, Limited.—The annual return of this company, made up to the 2nd inst., was filed on the 5th inst. The nominal capital is £60,000, divided into 7,000 first preference shares, 1,000 second preference shares, and 4,000 ordinary shares of £5 each. 10,505 shares are taken up, and of these 4,000 ordinary and 1,000 second preference are considered as fully paid. Upon 5,505 first preference the full amount has been paid, the calls paid amounting to £26,275, and unpaid to £1,250.

Pilsen, Joel and General Electric Light Company, Limited.—A meeting of this company was held on the 5th inst., when an account was given as to the manner in which the winding-up of the company has been conducted and its property disposed of. The notification of the meeting was filed on the same day.

Tilbury Portland Cement Company, Limited (manufacturers of concrete and metal telegraph poles, signals, tubes, &c.).—The statutory return of this company, made up to the 12th ult., was filed on the 18th ult. The nominal capital is £25,000, in £5 shares. 2,992 shares have been taken up, and £2 per share has been called. Upon 200 shares the full amount is considered as paid. The calls paid amount to £5,422 10s., and unpaid to £161 10s.

District Messenger Service and News Company, Limited.—An agreement of the 6th June (filed 1st inst.), with C. T. Russell, provides for the purchase of the "improvements in electrical signalling apparatus for police service and the like" (provisional protection, No. 6126, granted to R. D. Radcliffe, 22nd April, 1890). Also "Improvements in and relating to printing telegraphs, and to the distribution of news transmitted thereby"

(provisional protection, No. 8031, granted to R. D. Radcliffe on 22nd May, 1890). The purchase consideration is £39,750, payable £15,000 in cash and the balance in fully paid shares. The company will also take over the office of the vendor at 4, Northumberland Avenue, with all instruments, furniture and effects therein at such price as may be determined by a valuer to be appointed by the directors.

An agreement of the 29th ult. (registered 1st inst.) stipulates that the vendor shall not be entitled to require the company to make any payment in respect of the cash portion of the purchase consideration under the principal agreement, except as provided by the following articles. All money received by the company for subscriptions in respect of the first 4,000 shares of the company subscribed for in cash shall be retained for working capital. All moneys received for subscription for shares beyond 4,000, up to the sum of £15,000, to be paid to the vendor. If the full amount be not paid before the 29th August, he will be entitled to require the company to forthwith allot to him or his nominees fully paid ordinary shares, equal to the nominal amount remaining unpaid.

An agreement of 1st Sept. (filed 3rd Sept.) cites that only £1,890 has been paid in cash, and in accordance with the vendor's request the company will allot fully paid shares to the amount of £13,050, being the balance of the £15,000 payable in cash.

International Okonite Company, Limited.—The registered office of this company is now situate at 98 and 100, Queen Victoria Street.

CITY NOTES, REPORTS, MEETINGS, &c.

The Brush Electrical Engineering Company, Limited.

The first annual general meeting of the company was held at the Cannon Street Hotel, on Monday, the 8th inst., Lord Thurlow in the chair.

The Chairman, in moving the adoption of the report (printed in our last issue) and accounts to the 30th June, 1890, said that as this was the first opportunity he had had of addressing the shareholders at an annual meeting, he might, perhaps, be pardoned for saying a few words in description of the position of the company, and the financial and other results of the amalgamation. Although at the statutory meeting of the company, held on the 25th November, it was reported that the amalgamation with the Australasian and the Falcon Companies had been satisfactorily carried out, yet, perhaps, at that time the amalgamation existed more or less on paper. It had now been made a reality. As regards the reconstruction of the Anglo-American Brush Electric Light Corporation, there was very little to be said beyond what they knew already. The Brush Company retained its works in the Belvedere Road and other places, in fact, everything it possessed, and, in addition, it had acquired some valuable assets. New shares had been issued to the old shareholders; that was to say, the old shareholders had received new shares in exchange for the old at the agreed upon rate. As regards the Falcon business at Loughboro', Leicestershire, no time had been lost in taking those works over, and about £20,000 had been spent in erecting new shops to enable the company to construct the heavy machines it was now called upon to make. As regards the Australasian Company, the original scheme had been that the company should take over the whole of that business, including patent rights and stores, and issue to them £45,500 in shares and £500 in cash. The negotiations had been very protracted, not owing to any unwillingness of either party, but owing to the difficulty experienced in adjusting some of the assets. They were now satisfactorily concluded, but with a certain modification, namely, that the Brush Company, instead of taking over the stores, floating assets and liabilities, agreed to take over only the patents and the shares in the Melbourne Company, and to issue £31,000 in fully paid up shares to them instead of £41,500. Subsequent negotiations which took place had been owing to the inability of the Australasian Company to give a good title to everything that had been scheduled. They were matters of no material importance, but a certain deduction had had to be made on account of them. The financial result had been that the Brush Company took over the patents and shares of the Melbourne Company for £27,500 in shares, two-fifths ordinary and three-fifths preference. Had it not been for the conciliatory attitude of Mr. Van Tromp, the chairman of that company, and the liquidators, the difficulties in the way of the amalgamation might have been insurmountable, which would have been unfortunate. Negotiations were still on foot with a view to the Brush Company taking over the whole of the Melbourne Company's stores. From

the first the Brush Company had said that they would not take over its assets and liabilities, and that decision had been adhered to. The amalgamation had opened up to the company an enormous field for business, and one which would require very considerable energy on the company's part to do justice to. To obtain a fuller grasp of the position occupied by the company in that part of the world the directors had requested Captain Rowan to come over from Australia to advise them on all points. He came, and lengthy meetings had been held, and every point thoroughly sifted. Finally, satisfactory terms had been made for engaging him for a term of years to look after the company's interests and take charge of its business in Australasia. The final result of the issue of shares had been as follows:—To the Anglo-American Brush Company £156,942 ordinary and 104,628 preference shares; to the Falcon Company £33,305 ordinary and £22,200 preference shares; to the Australasian Company £16,500 ordinary and 11,000 preference. The balance of capital appearing in the report and balance sheet had been raised by subscription, making in all an additional £24,192 in ordinary shares and £164 in preference shares; and after all these transactions the company had only £256 10s. as outstanding arrears. They would, he thought, agree that that was a satisfactory result. Those arrears would, he hoped, very shortly disappear. The £75,000 debentures issued by the new company could, of course, only be so with the consent of the existing debenture-holders of the old Brush Company. That had been obtained; that was to say, those debenture-holders had been induced to convert their debentures or they had been paid off. They had behaved in a very friendly spirit, and the debenture charge on these great properties was very light indeed. Those debenture-holders had agreed to take the new debentures with the exception of £7,900, which had been purchased by the liquidators of the old company, and formed a very valuable security for any shareholder who liked to get 6 per cent. for his money. He thought it more desirable to keep those debentures, and, for his own part, would be prepared to take up some, and he strongly urged the shareholders to absorb them: They would be retained by the directors for a time for that purpose, and there would be no difficulty in disposing of them. As to the general efficiency of the combined works which the company now has: The Brush works in the Belvedere Road were in themselves very perfect, and the Falcon works by themselves were extremely satisfactory for the acquisition of work; but the combination of the two for the carrying on of electrical engineering formed an unrivalled position. The situation of the Falcon works was everything that could be wished as enabling the company to obtain the best and most skilled labour and the cheapest fuel. Moreover, they were on one of the main lines of railway, viz., the Midland, the Loughboro' station of which had sidings actually adjoining the company's works. Taken in conjunction with the Lambeth works, they enable the company to distribute its heavy work and its fine work most satisfactorily. The Falcon works occupied about seven acres of freehold land, or 35,646 square yards. About two-thirds of that space was built upon with the old shops taken over and new ones subsequently erected, leaving unoccupied land of about 12,900 square yards. The lifting power provided at the new works was very extensive and complete. The largest size of machine the company at present turned out was the Victoria-Morley dynamo, and they had already in course of construction a dozen machines of more than twice that size, that was to say, 30 tons. Of course, very heavy cranes were required, and the foundry was fitted with all that. The company was now able to cope with work of almost any magnitude. As regards expenses and profits: the latter appeared in the balance sheet; they would find that the expenses had slightly increased, but that was unavoidable, if they considered the vast body of work done, the expenses of the amalgamation, and of securing these additional works at Loughboro', &c. The expenses had increased from £11,131 in 1888 to £16,000 in the present year, and he did not think he could hold out very much hope of their being much reduced in the future. The directors would do what they could. There had not been, nor would be, any extravagance or want of care and attention. It was one of the inseparable results of extending business. As regards liquidators' balances, £9,979, he thought the shareholders would make their minds quite easy. No less than £7,900 represented the debentures of the old company which had been purchased by the liquidators, and the balance consisted of sundry small debts and accounts. As regards the litigation with the King-Brown Company, they were bound to take the case to the House of Lords for two reasons—first, because the English court of law had originally decided the case in their favour; and, secondly, to justify their having taken royalties from every manufacturer in Great Britain for some years past. Of all other litigation the company had pretty well washed its hands. Then, as regards their policy in reference to a matter of importance second to no other in the electrical world, viz., the obtaining of provisional orders; the directors had, as a general rule, confined their applications to places in which the company had interests to serve, like Bournemouth, Cardiff, and others more numerous than might be supposed. They had acquired the Bournemouth order, and also one-third of the City lighting. The City had been divided for this purpose into three great districts, and the Brush Company had acquired the central one, which was certainly not second in importance to any of the others. The company had to carry out the work under very favourable conditions, and strict but not impossible terms as to date; in fact, it had still some months before it would be compelled to commence the work. The cost of carrying it out would amount to some £300,000, and it formed a very valuable asset. The company em-

ployed some of the most experienced of the men connected with electrical and engineering work. The latter was almost as important as the former, and no company that did not combine to the utmost experience and knowledge of both could hope to carry out satisfactorily such an order as this. As regards the dividend—the profit and loss account showed a gross profit of £36,698, and after deducting all standing charges there remained a balance of £14,235. Out of that the directors proposed to write off £3,000 on account of property and patents, to apply £625 to reduction of preliminary expenses, and write off £500 on account of a small sum of £1,500 spent, and still being spent, in obtaining provisional orders. That left a balance of £10,426 to be appropriated. Out of that, of course, had to be paid dividends due on preference shares for the six months from February 10th to now, viz., £3,505, an interim dividend of £3,808 6s. 10d. having already been paid. Altogether, then, it was proposed to pay a dividend of £7,313 11s. 4d. on the preference shares, and to carry forward a balance of £2,796 to the next account. It was, perhaps, an act of purism to write off £500 on account of that £1,500 for provisional orders and £3,000 on account of the property account. The shareholders were not compelled to consent to it, and in that case they would have £6,800 available for a dividend on ordinary shares. They could if so disposed appropriate and divide a dividend on the ordinary shares for the past twelve months of 3 per cent., after paying the dividend on the preference shares and the debenture charges and every other legitimate expense, and that without taking into account any profits accruing from the Australasian branch. The directors, however, did not recommend that course, but that it should be appropriated as suggested in the balance-sheet. It was necessary the company should occupy in the future a strong financial position as well as a strong manufacturing one, and no company could do so unless it acted on certain recognised rules, one of which was to write off from the property and patents account as much as it could afford, and also a portion of other charges of an exceptional character. The scheme proposed by the directors was in accordance with sound finance. He did not anticipate their having to raise the £300,000 for the City order—the company would be paid on account as the work progressed—but undoubtedly a work of that magnitude could not be entered upon unless with a certain amount of ready money. They must, therefore, not be surprised if required to raise additional money, and should the event occur, it was essential that their last balance-sheet should appear sound. He moved the adoption of the report and accounts.

Mr. Van Tromp, in seconding, said he could give his assurance that the company was on the high road to being a very great success. He had inspected the works at Loughborough, and he did not hesitate to say that, for the purpose, there were very few premises in England better adapted. They possessed appliances which would enable the company to do everything connected with electrical motive power, from the commonest electrical apparatus to a large electrical car, an engine, or anything. The chairman had omitted, with regard to the Australian transfer, to mention that it comprehended the Cape of Good Hope and India. India he looked upon as a future grand field for electric lighting: it was a country of luxury and wealth, of enormous incomes, a very warm climate, in which electric lighting as against gas must be immensely favoured. Nor had any allusion been made by the noble lord to the company's works in Vienna and Austria-Hungary. The former were carried on at considerable profit, which was gradually increasing. The company had a great future in Vienna. As regards the Hungarian business, from the very latest advices received, it was a positive fact that electric lighting was completely beating the old gas company. It was believed that the whole lighting would shortly be in the hands of the Brush Company, to which very large profits must ultimately accrue. The directors would only be satisfied with giving the shareholders not merely a good but a handsome dividend. Everything was now in the most perfect working order.

Mr. Smart, a shareholder, thought the directors ought to be made acquainted with the feeling of the shareholders with regard to the non-receipt of any dividend for some years past. They had heard exactly the same promises for the future as they had done for some years past; but the result to the shareholders had been very different. The chairman said it was a new company; to the shareholders it was merely a change of name.

The Chairman reminded the speaker that the shareholders were getting a dividend.

Mr. Smart said something like 2 per cent.; a nominal dividend, certainly.

The Chairman said there was a dividend of 6 per cent. per annum on the preference shares.

Mr. Smart was not to be deluded. Like every preference shareholder, he also held a large amount of ordinary stock. Their receipts were really under 2 per cent. They felt greatly disappointed.

Mr. Ward would like to hear the charge of £8,000 for salaries explained. He hoped the directors were alive to the importance of electrical traction, and would be prepared to take the lead. Like other shareholders, he was anxiously looking forward to receiving a dividend on the ordinary shares, but he thought the board had done wisely in making the distribution as they had done.

Another Shareholder asked whether failure of the appeal in the King-Brown case would imply that the company would have to refund the royalties actually received by it.

The Chairman, in reply, said he anticipated a great development in the electrical industry to result from the recent removal by

Parliament of restrictions which had been quite prohibitive, and also from the public having become awake to the advantages which electricity offered. He had omitted to include in his former remarks the relative cost of manufacture in London and in Loughboro'. This as regards price of labour, coal, castings, &c., was very considerably in the company's favour. The £8,000 for salaries included those of the manager, sub-manager, skilled electricians, draughtsmen, managers at Loughboro', Vienna, and in Australia; in fact, a vast number of highly skilled men, and everything except directors' salaries and workmen's wages. The electrical tram car business had been beset with difficulties of various kinds, but it was now emerging from those difficulties, and it was one of the objects the directors had had in view when amalgamating with the Falcon Works, which were so admirably adapted for the manufacture of those cars, and which, moreover, placed the company in actual touch with the present users of horse cars, a great number of which had already been turned out by the Falcon Works. Only the other day the company received an order from the London Road Car Company for 60 busses. The works were also well adapted to the manufacture of electrical launches. The company was making a great many engines at Loughborough. The royalties referred to had been received by the previous company, and whatever might be the decision of the House of Lords, they were not recoverable from the Brush Company. All that would happen would be that the company would receive no more royalties.

The motion was then put, and carried unanimously.

The Chairman also moved to declare a dividend on the preference shares of 6 per cent. per annum for the period from 10th August, 1889, to 30th June, 1890; and that the balance dividend (after payment of an interim dividend on the 1st March last) be paid on the 19th September next.

The motion was agreed to, and, with a vote of thanks to the chairman and directors, the meeting dispersed.

Commercial Cable Company.—The transfer books will be closed from September 20th to October 2nd, for the payment of the usual quarterly dividend of 1½ per cent. on October 1st.

National Telephone Company.—The committee of the Stock Exchange has ordered 2,284 additional shares, No. 436,701 to 438,984, to be quoted in the official list.

TRAFFIC RECEIPTS.

The Great Northern Telegraph Company, Limited. The receipts for the month of August amounted to £25,000; 1st January—31st August, 1890, £181,000; corresponding months 1889, £178,200; do. 1888, £170,700.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending September 8th, after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited, were £4,590.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.—LEEDS, 1890.

ELECTRIC LIGHTING AND FIRE INSURANCE RULES.

By WILSON HARTNELL.

(Read before Section G, September 8th, 1890.)

Introduction.—Every system of artificial illumination involves some risk from fire. Electric lighting, although it may be the safest of lights, is not exempt from this danger.

Until recent years, insurance companies have given their attention to framing regulations for checking the spread of fire when once it had originated, rather than devising means for preventing an outbreak.

The early inexperience and ignorance of many who undertook electric lighting, and consequent accidents, rendered some guidance and restrictions absolutely necessary for protection against fire. No authority existed. The Society of Telegraph Engineers proposed a few obvious regulations which were accepted by the majority of insurance companies as sufficient. Comparatively recently the Electrical Society have framed a much more elaborate, and an admirable set of suggestions. Meantime the Phoenix and many other fire offices have formulated conflicting rules of their own, which they more or less enforce.

I say advisedly, more or less, because on the one hand, in the absence of any comprehensive and competent system of inspection on the part of the insurance companies, and their different requirements, and, on the other hand, in their desire not to lose business, no standard of excellence is attempted.

Much is left to the conscience or ability of the contractor, which is unjust to those who abide by the best rules.

Large numbers of persons and millions worth of property are affected by these rules.

The object of this paper is to point out much needed amendments.

Such rules should be based on the deductions of experiment and the teaching of experience. They should give the utmost freedom of action and encourage progress. They should contain the minimum that is necessary, and this should be strictly enforced. Above all, these rules should be in accordance with the general principles which regulate all successful engineering constructions. For example, if we consider such familiar but different structures as a locomotive engine, a steamer, a bridge, we shall observe that there is no absolute safety in any one of them. Each has been perfected, not by directing the mind to a particular class of facts, but by a judicious compromise between many conflicting necessities, by giving neither more nor less than a just measure to each requirement, and in each case, all this has had to be done with due economy and limited means. In this spirit, all fire insurance regulations should be framed.

Conductors.—In regard to conductors, my first point is to show that any attempt on the part of the insurance companies to determine a fixed current density is useless, vexatious, and scientifically wrong.

For any electric light installation it is necessary to limit the fall of potential in the more distant lights. This can only be done by so limiting the current density that there is not the remotest chance of fire from over-heating of the wires. For example, suppose the fall of potential between the brightest and dimmest lamps were limited to 4 per cent., and the most distant lamp was 75 yards from the dynamo, then the mean current density must not exceed 1,600 amperes per square inch. If the distance be 100 yards, 1,250 amperes per square inch; if 150 yards, 800 amperes, and so on. In any electrical installation in a large building, it is convenient to sub-divide the lights into groups, dependent upon their distance, and to adopt a table of wires and lamps on the several circuits corresponding to these mean distances, and thus secure comparatively uniform brightness. If, however, an arbitrary rule, such as 1,000 amperes per square inch be insisted upon, this rational principle of lighting cannot be adopted. It is, of course, necessary to adopt some limits of currents, but these depend upon the sizes of the wires, as it is easily shown by experiment and reasoning that the larger the cable the less must be the current density. However small the current, the smallness of the wires must be limited. For example, No. 20 S.W.G. is perhaps the smallest size that should be used, for fear of mechanical injury. In mansions, &c., where the first cost of wiring is of less consideration, and where the wires are placed out of sight, No. 16 S.W.G. may be the limit of smallness. Such details are best left to private judgment, but should be stated on the insurance policy.

That wires can be made red hot by electricity, and give rise to fires, was one of the most obvious facts thrust upon the notice of the insurance companies, and apparently almost the only one they could imagine or comprehend. This danger has been greatly magnified. It is, moreover, the danger most easy to absolutely abolish by judiciously arranged cut-outs.

The current required to heat wires has been the subject of many experiments. The most complete results published were those of Mr. W. H. Preece in 1888 and of Mr. A. E. Kennelly in 1889.

Experiments on Wires.—The smallest wire used in electric lighting is the twin flexible wire, equal in section to that of No. 22, S.W.G. It usually carries one lamp and consists of 23 strands, six mils. diameter. (Specimen silk and asbestos covered.)

This experiment shows that one strand only suffices to light a 110 volt 16 C.P. lamp requiring about 58 amperes. This pendant of 23 such strands is therefore absolutely safe with one lamp.

The current density in this small filament is 20,500 amperes per square inch.

This filament will carry three such lamps, say 60,000 amperes current density, without being hot enough to burn anything. It becomes dull red hot with five lamps and a current density of about 100,000 amperes per square inch. It must be remembered that the heat increases as the square of the current, so that with five lamps there is five times five, or 25, times as much heat as with one lamp. This is an extreme case of high current density. Another opposite extreme case I recollect was that of a lead-sheathed cable carrying about 400 amperes with a current density under 700, the temperature of which was found to be 135° Fahr. on a cold day. These extreme cases illustrate the absurdity of a fixed current density regulation.

Experimenting further with this small stranded twin wire, it will be seen that it easily carries eight or ten lamps—in fact, that it may be used to supply a 200 C.P. lamp. According to Mr. Kennelly's experiments, No. 22 = 28 mils. will require about 17 amperes to raise the temperature 100 degrees in wood casing. This is about 30 lamps of 16 C.P., 110 volts, or 27,000 amperes per square inch, current density.

It may therefore be pronounced to be absolutely safe with two or three 16 C.P. lamps. The current required to make the insulation smoke is about 30 amperes, or about fifty 16 C.P. lamps. The temperature which a wire attains, through which any steady current is flowing, obviously depends upon the facility with which the heat escapes by conduction, convection, or radiation. So that the current which makes a wire red hot or melts a flexible wire may be more or less. (Exp. a 1,500 C.P. lamp with 35/40 = No. 23.)

The smallest solid wire used in electric lighting is No. 20—36 mils., which at 2,000 amperes per square inch would carry one

ampère, say two lamps; but would seldom be used for more than one lamp.

This wire, according to Mr. Kennelly's experiments, will require about 23 amperes in wood casing to raise the temperature 100° . It will carry, as here shown experimentally, a 1,500 C.P. lamp, and remain comparatively cool, whilst no less than about 80 lamps or 50 amperes are necessary to destroy it. No. 16, at 2,000 amperes to the square inch, would carry six lamps, but is here shown to be comparatively cool with 50 lamps.

I have allowed 40 amperes to flow through such a wire for a long time without much injuring it, equal to 70 lamps, or over 12,000 amperes per square inch; to burn off the insulation 100 amperes, say equal to 170 lamps are required. It is therefore absolutely safe to use 10 such lamps, which cause less than $\frac{1}{100}$ th the heat to set it on fire.

SUNDRY EXPERIMENTS.

No. 18 destroyed with 70 amperes.

7/20 insulation melted with 110 amperes.

I have observed 19/16s carrying 180 amperes for hours—about 2,900 amperes current density. It becomes warm—according to Mr. Kennelly's experiment the temperature would be raised some 40 degrees.

The scientific rule is that of the Institute of Electrical Engineers, that the wire is to be at least of such size that double the current would not raise the temperature 150° . This limit for an initial temperature of 75° , calculated from Mr. Kennelly's formulae gives $c = 560 d^{\frac{2}{3}}$, and might well be adopted by the insurance companies.

These experiments on the smaller wires used in electric lighting, made not only with a current meter, but with the lamps before our eyes, have demonstrated that there is not the most remote danger of fire with the currents ordinarily used. That on the smallest wire even 10,000 amperes current density would be safe (as safe as 500 current density on mains for 400 amperes), and that for insurance companies to fix a current density, is useless, vexatious and scientifically wrong.

Fusible Cut-outs.—Fusible cut-outs seem to be regarded with some mistrust. The point I desire to establish is that by their means the mains and branches may be absolutely protected from danger by fire.

The highest current will be required to melt a cut-out when it is short, and itself and connection cold—when it is longer or covered up, and heated gradually, a lower temperature melts it.

A sudden rush of about twice the current may pass through, melting the cut-outs explosively.

Experiment of Cut-out melting by Degrees, and Sudden Rush.

A copper wire will likewise take more than double a dangerous current without harm in a momentary rush. On one occasion I observed a short circuit through a No. 16 wire, throw off a magnetic cut-out supposed to be set at 350 amperes, without damaging the insulation of the wire.

The first point to notice is that the fusible wire melts at less current than the copper wire gets damaged.

The next point is to prove experimentally that wires are efficiently protected by fusible wires of the same diameter; and this is the only point that insurance companies need trouble about. So long as wires are efficiently guarded, it is no business of theirs what the working current may be.

It may be experimentally shown that even larger cut-out wires would protect copper.

But this is bad practice since, in most cases, much smaller cut-out wires can be used—especially in the larger mains.

There is some danger of the flash from a sudden rush lighting inflammable dust, if so fixed that such dust can settle on them.

The subject of the construction and position of cut-outs is most important, but would require a paper to itself.

Experience has led me to regard good cut-outs properly fixed and wired with almost implicit confidence as protecting the wire.

Contacts.—In an experience extending over seven years, all the dangers of fire have proceeded from imperfect contacts (with two exceptions). In two cases the wires were cut in two by carpenters, not concerned with electric lighting. In one case a fire arose from the slackening of a binding screw through shrinkage of wood. The resistance of a well-scrapped contact is considerable, but loose screwed contacts get hot with even 5 ampere currents. Broken wires with ends in contact are sure to set the insulation on fire through sparking. Insufficient area of contacts leads to heating. Cut-out wire requires specially good contacts to prevent melting at their ends from this cause.

Experiments on Contacts.

Cut-outs are no protection against heating and sparking from imperfect or broken contacts. The following rules are useful:—Avoid screwed joints as much as possible; screw them up tight, with good areas of contact; on no account allow them out of sight. Solder every connection as far as conveniently practicable.

All sharp kinds in solid wires to be cut out, not straightened. Use standard wires as far as possible. Put no very small wires out of sight.

Intelligent and conscientious workmen are desirable to obviate this contact danger.

Cut-outs must be placed in conveniently accessible positions. Short circuits readily occur at the lamp-holders chiefly from meddlesome curiosity, but are almost impossible elsewhere if the wires are properly fixed and let alone, so that the risk of moving the cut-out from the root of the branch is about zero. It is easy to make this assumed risk absolutely zero, for if the cut-outs be no larger than the branches they protect, each wire has a second protection in the cut-out of the next superior branch.

Experience with cut-outs shows that if only a small margin be allowed, they are after a while liable to melt with the working current, apparently from deterioration of contacts and gradual accumulation of heat. In fact, cut-outs seem only too ready to melt, and are absolutely trustworthy to prevent fire from excess of current.

The insulation required for telegraphic work and that for electric lighting work are not necessarily the same. In the former the wires extend for hundreds of miles, and the storage of energy in the batteries is both costly and limited. In electric lighting the wires are short and power abundant, most engines could easily be improved from 10 to 15 per cent., and the owners will not incur the small expense, so that 1 or 2 per cent. leakage of electricity, which would be considered enormous, is almost of no consequence from a prime mover point of view (so to speak).

The chief object of electric light insulation is safety; and this safety, like that of a steam boiler, should be not for one or two years, but for as many years as possible. Durability is, in my opinion, of far more consequence than high insulation. I therefore consider naked wires on insulators (where practicable) the best of insulation, and I regret to say that I look upon vulcanised India-rubber with some distrust. Exposed to the air, vulcanised rubber often cracks, and more or less perishes in a few years. It may be that when held together and protected from the air, as it is in the cable, it may last for say 20 years or more. For damp places, vulcanised rubber is indispensable, or some waterproof insulation.

Recollecting that all work has to be done with limited means, and at some risk, it is very important to have clearly defined what wires will pass the insurance companies, and under what circumstances, and at what premiums.

Here are specimens of wires by two London and two Manchester firms:—

1. Single rubber-covered wires, which appears to me the least insulation desirable for wires in casings.
2. Double rubber-covered wires.
3. Light vulcanised rubber-covered wires.

The prices of similar qualities by different makers are much the same. But the price of single rubber-covered is 20 per cent. less than that of double rubber-covered, and light vulcanised about 40 per cent. more than double rubber-covered.

Any of these wires when dry, the insulation per square foot in area is very great, and a low insulation means local faults, perhaps one local fault which may be a source of danger. On the other hand, the insulation is very much lowered by damp weather.

To overhaul an installation so thoroughly as to trace and eliminate every slight fault would involve far more labour than is ever likely to be taken. Hence the greatest protection, in my opinion, is to be obtained by using good material and good workmanship throughout, and not trust to merely insulation tests only.

A bad job may test well, and *vice versa*.

It is not fair to demand very high insulation tests for wires without also specifying the quality of insulation. Because a single rubber wire, or possibly a wire innocent of India-rubber, may test as well as vulcanised wire in dry weather.

It must also be remembered that although the insulation of the bases of the switches and cut-outs is high, yet in the aggregate (if the switches, &c., be numerous), they will reduce considerably the total insulation. If the test be between the positive and negative wires, the lamp fittings will greatly reduce this, so also that of the twin wires for the pendants, the insulation of which I have known to vary from 120 megohms per mile when dry to 48,000 ohms per mile when soaked in water and drained.

I find the ordinary twin flexible asbestos, covered, to be 10 to 20 megohms per mile.

Thus, for testing to be fair, it must be stated how the tests are to be made.

Casings.—The casings are mechanically useful to protect and support the wires; they have the disadvantage, putting it from an insurance point of view, of concealing it.

They no doubt assist the insulation.

The space between the grooves has now been reduced to a reasonable width, at the same time it seems unreasonable to put all qualities of wire on the same footing. It seems to have been forgotten, curiously, that when switch wires, say positive, are laid on a positive wire and switched off, they become negative. The possible current through them is no doubt limited to that which would go through the lamps.

Seeing how much this practice is followed, and its convenience, it is another argument for the use of good wire, with which under such circumstances accidents are hardly conceivable.

The use of varnishing casing seems very doubtful; if the place be not damp it can be of no service; if it be damp then a wire that will stand damp ought to be used.

Non-inflammable paints, to prevent the casing taking fire, seem

to me ridiculous. There can be no remote risk of fire in the casing, if the work be properly done.

Of switches very little need be said on the main sections, double pole switches are convenient, but on the branches double pole switches and double pole cut-outs, by the extra expense and complication they would entail, would more than defeat any imaginary advantage urged by their advocates.

Equity of Rules.—The grievance of ill-framed and conflicting fire insurance rules is not only that they interfere with the carrying out of the work in the manner best suited to the circumstances, but there is difficulty in knowing what is required, by insisting, or appearing to insist, on a certain class of material, &c., in one case, and passing very different things in another; there is a further difficulty in not knowing what they will pass.

Those who require the electric light, and know nothing of the matter, are still further bewildered, and are apt to accept the work which is the least expensive, so that the insurance companies defeat the professed object.

It appears, from some recent correspondence in the *London Times*, that of 33 offices, ten offices use the Phoenix rules, ten others have their own special rules, seven deal with each risk as it arises, six use the Institution rules.

In conclusion, I would most strongly urge that the rules of the Institution of Electrical Engineers, with perhaps a few additions, be accepted by all the fire insurances.

ALTERNATING VERSUS CONTINUOUS CURRENTS IN RELATION TO THE HUMAN BODY.

By H. NEWMAN LAWRENCE, M.I.E.E., and ARTHUR HARRIES, M.D.

THE present paper is supplementary to a preliminary paper on the same subject read before the Institution of Electrical Engineers on the 27th March, 1890.

In that paper it was stated (*Soc. Journal*, Vol. 86, 1890), that "our experiments have not been made with the powerful currents dealt with in electric lighting and distribution of power," and this admission together with the difficulties inseparable from the accurate measurement of alternating coil currents are points in connection with our paper which have given rise to much discussion in the electrical and other journals.

In the present instance, however, we have endeavoured as far as possible to obviate criticism on these grounds.

1. By using currents directly from lighting circuits—both alternating and continuous.

2. By using currents directly from a dynamo whose rate of alternation could be accurately ascertained.

3. By using currents of high E.M.F.

4. By using an instrument for the measurement of alternating currents, whose accuracy at the reading of our former paper was theoretically questioned by one or two speakers, but which has since been tested and proved to give correct readings by an eminent practical electrician (see page of *Soc. Journal*, Vol. 86, 1890), thus confirming the accuracy of the readings formerly recorded by the instrument, as well as those which are contained in our present paper.

Another practical point to which special attention has been given in this paper is that our experiments have been made chiefly with the skin in a state of nature, so that the conditions of experiment as nearly as possible resemble those which might be expected to exist under accidental circumstances, that is to say under circumstances when contact with the conductors was unexpected and therefore unprovided for.

With so much brief preface, we proceed to give in detail the results of several series of observations made under the conditions explained at each step.

RESISTANCE.

In dealing with the resistance of the human body many difficulties present themselves and render it by no means easy to arrive at definite data thereon. The complicated structure of the body at once prohibits any attempt to regard it as an ordinary inanimate conductor. Several methods have been tried or suggested. The Wheatstone bridge method which we previously adopted, was shown to be inaccurate by Mr. Otto T. Blathy, in the *Electrician*, of April 25th, 1890, and the unsatisfactory nature of comparisons made between resistance measurements taken with the E.M.F. of a few battery cells and those likely to result from the use of an E.M.F. such as is common in light and power circuits has been pointed out by several of our critics.

We have, therefore, thought it best to obtain our resistance measurements by passing the current direct from a light circuit through two or more bodies in series, and then, by noting the current strength passed and the E.M.F. used to pass it, to calculate the resultant resistance.

For this purpose we used in the first case dynamo generated continuous current taken from the lamp leads at the Institute of Medical Electricity, which is supplied by the St. James's and Pall Mall Electric Light Company. Having disconnected a lamp the voltage was tested, and found by a Cardew voltmeter to be 104. We then connected up two metal electrodes of 45 square centimetres area each, which could be grasped in the hand, putting in series therewith only a milliamperé meter having 755 ohms resistance and a key. Two persons joined hands, and each grasped one of the electrodes with his free hand. Circuit was then completed and the reading taken.

The results are set forth in the following tables:—

TABLE A.—RESISTANCE TO CONTINUOUS CURRENT.

Group.	E.M.F. in volts.	Current strength in M.A.	Total R.	R. of milliamperé meter in ohms.	Resultant R. of each person.
1, two persons	104	7.5	13,866	755	6,555
2 "	"	5.75	18,086	"	8,666
3 "	"	7.25	14,345	"	6,795
4 "	"	9.25	11,243	"	5,244
5 "	"	9.5	10,947	"	5,066
6 "	"	8.0	13,000	"	6,122
7 "	"	10.0	10,400	"	4,822

Average 6,185 ohms.

In the second case we used a dynamo generated alternating current, taken from a Siemens dynamo at the School of Electrical Engineering, Hanover Square, which was kindly placed at our disposal by the managers (Mr. Wm. Lant Carpenter and Mons. Leon Drügman). The arrangements for connection were exactly the same as those described above for the continuous current, except that groups of four and five persons joined hands instead of only two. The same Cardew voltmeter, the same milliamperé meter, the same electrodes were used.

The voltage varied from 115 to 137 and the alternations from 60 to 75 per second.

TABLE B.—RESISTANCE TO ALTERNATING CURRENTS.

Group.	E.M.F. in volts.	Current strength in M.A.	Total R.	R. of Gal.	Resultant R. of each person.
1, five persons	115	4	28,750	755	5,599
2 "	120	5	24,000	"	4,649
3 "	123	7	17,571	"	3,363
4 "	124	7	17,714	"	3,391
5 "	124	6	20,666	"	3,982
6, four persons	123	8	15,375	"	3,655
7 "	137	9.5	14,421	"	3,416

Average 4,008.

These observations show results widely differing from those obtained by other methods and indicate that while under these conditions the R. to the two forms of current more nearly approximate to one another, yet that to continuous current is still considerably greater than that to alternating. It is interesting to note that the average R. to alternating current obtained by this method closely corresponds to that obtained by Mr. Blathy and mentioned in his letter above referred to. He makes it from 4,000 to 5,000 ohms, and our results show an average of 4,008 ohms. We may state then in round figures that we find the resistance of the human body under the conditions named to continuous current to be 1.5 times that to alternating current.

We next endeavoured to find how far variations of the contact area would effect the result and obtained the following readings:—

TABLE C.

VARIATIONS IN CURRENT DUE TO ALTERATIONS IN CONTACT AREA
(E.M.F. being constant.)

Continuous dynamo current at 104 volts.

Total contact area in square centimetres. (Two electrodes, each having same area, one being grasped in each hand.)	Current strength in milliamperes.				
	Sub. 1	Sub. 2	Sub. 3	Sub. 4	Average.
90.0	10.0	10.0	10.0	10.0	10.0
45.0	7.25	5.25	7.0	5.25	6.19
22.5	6.0	4.75	5.75	...	5.5
9.0 Electrodes held by thumb and finger only.	5.75	3.25	4.0	...	4.3

From this it appears that in round numbers:—

A reduction in the cont. area of 50 per cent. reduces the current strength by 40 per cent.; a reduction in the cont. area of 75 per cent. reduces the current strength by 45 per cent.; a reduction in the cont. area of 90 per cent. reduces the current strength by 60 per cent.

It is manifest that to arrive at anything like a definite law on the subject a great number of readings must be taken, but we think the above results form a useful indication of the important bearing contact area has in determining the seriousness, or otherwise, of accidents in light and power circuits.

SENSATION.

In this part of our paper we propose to compare the results obtained when electrodes connected respectively with dynamo-generated continuous currents and dynamo-generated alternating

current are brought into and kept in contact for an appreciable time with the human skin in a natural state, that is to say, in the state normal to the person experimented upon at the time of testing. In order that this series might be complete, it would possibly have been better to give barometric, thermometric and hygrometric readings, of which we have taken many, but these data belong rather to a complicated side issue and do not affect the main question, to which this paper must necessarily be confined, so we have considered it best to omit them altogether, taking it that the subjects experimented on were in an average condition of health at the time, and that the atmospheric conditions were more or less like those to be expected in a climate similar to that of England.

The results are tabulated as follows:—

TABLE D.

Conditions.—Metal handle electrodes grasped in the hands (surface area 45 sq. c. each) in connection with dynamo-generated continuous current, taken from lamp leads, as before mentioned (Table A.), E.M.F. 104 v., by Cardew's voltmeter.

Subject.	Discomfort point.	Fixation point.
1	... 18 ma.	... not any.
2	... 15 ma.	... not any.
3	... 20 ma.	... not any.
4	... 22 ma.	... not any.
5	... 15 ma.	... not any.
6	... 20 ma.	... not any.
Average	18.3 ma.	Average

In each instance, burning sensation under the electrodes became unbearable after about 30 seconds; this was the only objectionable feature, though electrolytic action was sufficiently marked to induce slight blistering in two of the cases. We have to call special attention to the fact that in no case was muscular fixation, or any sensation approximating thereto, reached with the continuous current, nor have we at present any reason to suppose such a result possible.

TABLE E.

Conditions.—Metal handle electrodes grasped in the hands (surface area 45 sq. c. each).

Alternating current from Siemens's dynamo. E.M.F. 110 v. by Cardew's voltmeter. No. of alternations per second, 23.

Subject.	Current strength.	
	Discomfort point.	Fixation point.
1	... 3.0 m.a.	... 6.0 m.a.
2	... 3.5 "	... 7.25 "
3	... 4.5 "	... 6.5 "
4	... 3.5 "	... 8.5 "
5	... 4.0 "	... 7.25 "
Average	3.70	Average 7.10

TABLE F.

Alternating current from same dynamo as last table.

Electrodes, as last table.

E.M.F. 85 volts.

Alternations per second 68.

Subjects as before.	Current strength.	
	Discomfort point.	Fixation point.
1	... 3.5 m.a.	... 6 m.a.
2	... 4.5 "	... 8.75 "
3	... 3.75 "	... 8.0 "
4	... 4.75 "	... 8.75 "
5	... 4.25 "	not reached at 8.0 "
Average	4.15	Average 7.90

In Table E, it will be observed that the average discomfort point is 3.7, the average point of muscular fixation 7.10.

In Table F, the average discomfort point is 4.15, the average fixation point 7.90.

The mean of the two sets being 3.9 for discomfort point, and 7.5 for fixation point.

We wish to differentiate clearly between what we have termed discomfort point in connection with both varieties of current, and that which we have called the point of muscular fixation, which we have only been able to discover in experiments with the alternating current. This is the more necessary,

because herein lies one of the great differences in the danger of accidental contact with the two systems respectively.

To put it plainly, we have found no point at which it is impossible to release personal contact with a continuous current circuit, while it is easy with a comparatively low current strength to find a limit beyond which it becomes a physical impossibility to disengage oneself from contact with the alternating current circuit.

A little consideration will show that this cannot be too strongly emphasised, for while with the one, personal effort will suffice to release the sufferer, with the other the agency of a second person must be called into play before the dangerous action of the current can be stopped.

Many of the critics of our former paper appear to have failed to recognise this most important distinction, and to have regarded muscular fixation as synonymous with discomfort point.

Tables E and F were constructed from observations made on the same patients in the same order with the same machine, though with an interval of two days; in the first table the E.M.F. was greater (110 v.) and the rate of alternation less (23 per second) than in the second table, when the E.M.F. was 85 v., while the alternations were 68 per second.

In Table E fixation needed nearly twice as much current strength as discomfort, and in Table F the same sort of relation obtains, though in the latter instance the alternations were just three times as frequent.

During the discussion on the paper at the Electrical Engineers, on March 27th, Dr. Harries, in his reply, stated that "the more rapid the alternations the more nearly did the conditions resemble those present with continuous current as regards sensation." Putting aside for the moment the difference of E.M.F. in the two sets of experiments (25 volts) a comparison of Tables E F will fully bear out this statement, for we find that both average discomfort points and average fixation points are higher, though the alternations are so much more frequent in Table F.

It may not be out of place here to note that observations made with a Wheatstone's transmitter in another series of experiments, at about the same time, showed that a higher rate of alternations, with same E.M.F. and current strength, reduced the sensation.

It is conceivable and probable that nerve impulses travel as waves at a given average rate of speed (90 feet per second, Helmholtz). But sensations may follow one another so rapidly and so irregularly that one set of waves may impinge upon and modify the next preceding set, thus altering the total effect which would be produced upon cortical centres by a given number of sensations in a given time.

Alternations may be so rapid and irregular that these conditions are present in such wise, that the total effect of a series of shocks given at a certain rate of speed is less than the total effect of a similar number of shocks given at a lower rate of speed.

And it is only in this way that we are able to account for the power to bear larger current strength at a high rate of alternation, i.e., when the rapidity is over 50 or so per second.

SHOCK.

With continuous current shocks (sudden make or break), from dynamo-generated continuous lighting circuit with a current strength of 10 to 20 ma., the sensation was that of a sudden jerk, followed by feeling of heat at the points of contact with the electrodes, increasing until the sensation became unbearable. The make jerk was distinctly more marked and more unpleasant than the break jerk, though the latter was followed by an increase in the sensation of heat in the neighbourhood of the points of contact—the increase persisting for two or more seconds after contact was broken.

Shocks of alternating current from Siemens's dynamo-generated alternating circuit were also taken by the subjects concerned in Tables A, B, C, &c. A tingling sensation was felt, which rapidly increased to muscular contraction, becoming more and more unpleasant, and accompanied by a sensation of heat in the neighbourhood of the electrodes, though not immediately under the site of contact as in the case of the continuous current.

It was noticed that the maximum effect was not immediately felt, an increase being apparent for one or two seconds, the hands being still in contact with the electrodes. This effect was most apparent with small currents (2 to 3 ma.). As the current strength increased the maximum effect was more rapidly produced.

When 8 ma. were passed the effect seemed immediate. Considerable heating of the parts in contact with the electrodes, and of contiguous parts, was noted on both make and break shocks. This continued to invade adjacent parts during the period of continued closure of the circuit, and the general effect included muscular fixation in most of the subjects experimented on.

In our previous paper we concluded by deducing a danger ratio. This showed the danger of serious consequences on contact with the alternating current to be 41.5 times greater than that to continuous currents. So high a ratio was thought by many to be excessive, and the more recent experiments now set forth prove it to be so, if we calculate it on exactly the same lines as before. We find, however, that there are other factors which should be included in calculating the danger ratio, in addition to those used in the former paper, viz., "Differences in Resistance and Sensation." The difference in resistance obtained by the method we have now adopted and set forth in Tables A and B is 1.5 instead of 8.3, as obtained by the former method. The difference in sensation set forth in Tables D and E, on the other hand, is 4.7, or only 0.3 less than that obtained previously. This would give a danger ratio of 7.0. Such a ratio, though far below that obtained with small battery and coil currents, would be sufficiently serious to demand

very careful attention from electrical engineers, if it represented the whole state of the case; but it does not (as mentioned above) cover the whole ground, for we have also to consider two other factors, viz., difference in initial shock and difference in continued contact. On these two heads comparative values cannot be given. As regards initial shock, in which the time period of contact is a minimum, we have made many tests on various individuals, who one and all declare that the initial shock of alternating current of a certain strength is far worse to bear than the initial shock of continuous current of the same strength. This, from the nature of the experiments, can only be tested with small currents, and it is conceivable that with large currents such marked differences may not be observable, the time factor being left out of consideration. The second, however (continued contact) is a matter of far greater importance, as we have already pointed out in discussing muscular fixation. The time period of contact being appreciable with continuous current, we have no muscular fixation, and the subject of accident would be able to release himself. On the other hand, an appreciable time of contact being made with an alternating current circuit, the subject would be absolutely fixed *in situ* until released by extraneous aid, being exposed during the whole time to the full effect of the current passing through him. Further than this, the act of muscular contraction might, and probably would, increase the contact area, and so increase the current allowed to pass.

When, therefore, we take these last-named factors into account, it is manifest that the danger ratio of 41.5 to 1, named in our former paper, is by no means too high. We do not now name another figure, because it appears to us impossible to express in terms that could be used for calculation the differences in initial shock and in continued contact.

It may perhaps be expected that we should make some reference to the quantity of current which constitutes a fatal dose, but this can only be arrived at by careful observation of all the electrical conditions prevailing at fatal accidents or executions.

The difficulty of obtaining such information is generally very great as regards accidents, but surely not as regards executions. That the authorities in charge of Kemmler's execution failed to take measurements of the E.M.F. and current strength used, is almost incredible, and in view of the fact that they possessed so excellent an opportunity, such neglect seems quite inexcusable.

For some time past, we have been hoping that some information in this direction would be forthcoming, but the article by Mr. C. Huntley in the *Electrical World*, reproduced in the *ELECTRICAL REVIEW* for September 5th, 1890, appears to be conclusive, for it says, "No data of either the electrical or mechanical apparatus were taken."

Mr. Parry in his recent articles in American electrical papers, arrives at the conclusion that one ampère is an undoubtedly fatal current, provided it actually passes through the victim. This estimate we see no reason to differ from, though we hardly think sufficient evidence has been obtained on which to base definite conclusions.

We will now briefly summarise our conclusions, and in doing so desire to draw attention to the fact that they are based upon certain conditions, and, while we believe them to be sufficiently accurate and reliable under these conditions, we in no sense claim them as true under all conditions.

CONCLUSIONS.

A. When the human body, with the skin in its normal unmoistened condition, comes into contact for an appreciable time with bare metal conductors of a dynamo-generated continuous current passing at 100 volts in such a way that the current passes from hand to hand, and the total contact area is about 90 square centimetres.

1. A current of about 0.016 ampère will pass through it.
2. This current can be borne without discomfort for 15 to 30 seconds.

3. After about 30 seconds unpleasant burning sensations become marked and quickly increase.

4. The subject is perfectly able to release himself at will during any portion of the time of contact.

B. When the human body comes into contact with dynamo-generated alternating currents, alternating at about 60 to 70 per second under the same conditions as above.

1. A current of about 0.025 ampère will pass through it.
2. This current is six times greater than that which produces discomfort.

3. Instantly the subject is fixed by violent muscular contraction and suffers great pain.

4. The subject is utterly unable to release himself, but remains exposed to the full rigour of all the current that may be passing.

C. When circuit from electric light or power conductors is accidentally completed through the human body, the danger of serious consequences is many times greater when alternating than when continuous currents are passing at equal voltage, and this is still to a large extent true if the voltage of the continuous current be double that of the alternating.

- D. 1. With both forms of current a reduction of contact area materially reduces the amount of current strength that passes.

2. With the alternating current, if the rate of alternation be reduced below 50 per second, the sensations of pain accompanying muscular fixation will be increased, while if the rate of alternation be increased, the pain will be diminished.

Finally, we would remind those gentlemen who so commonly speak as if voltage were the chief or only factor in the danger of accidental contact, that current strength is the important item, and

that according to Ohm's law current strength is dependent not only upon E.M.F., but upon the total resistance in circuit at the time of accidental contact.

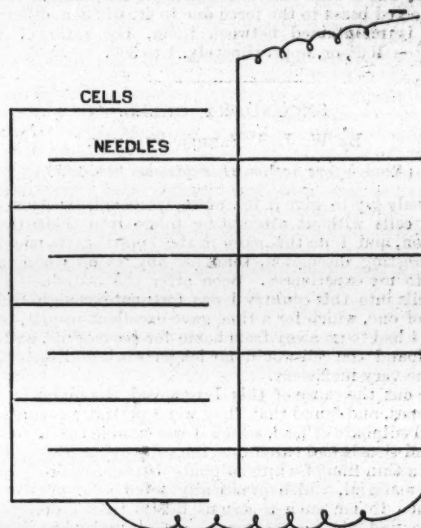
To make statements based upon voltage only, such as newspaper reports of a recent execution have contained, is not only distinctly misleading, but calculated to induce the uninitiated to form erroneous conclusions.

ON AN ILLUSTRATION OF CONTACT ELECTRICITY PRESENTED BY THE MULTICELLULAR ELECTRO- METER.

By Sir Wm. THOMSON.

(Read before Section A, September 4th, 1890.)

CONTACT electricity of strong metals absolutely removed from possibility of chemical action is a subject which was formerly much discussed, but now the fact of that kind of action is thoroughly admitted, and most of the natural history of the subject is pretty well known. I have not to-day to add to the knowledge of the subject, but merely to remark that it brings out a very curious feature in electrostatic instruments, in illustrating its application to this instrument of contact electricity. The metals in question are brass and aluminium. I am sorry I cannot show you the interior of the instrument just now, but a sketch will probably make it understood. The instrument consists in a multicellular electrometer. In its working it is a number of cells, as the designation indicates, with a needle, or a number of needles, moving under the influence of these cells. There are 20 cells; one over the other, and we will represent this in section.



There are 10 cells acting on one set of ends and 10 at the other. The needles are mounted one above the other on a stem, which hangs by a fine platino-iridium wire. The principle is simply this—the needle is connected through its fine wire with the outside case of the instrument, which is one of the metals between which the difference of potential has to be measured. The other metal is the cells—this pile of cells and the other pile of cells are metallically connected. They are insulated from the outer case of the instrument, and we have a binding screw here connected metallically with the cells, and insulated from the case of the instrument. In the quadrant electrometer contact electricity was illustrated by making the two pairs of quadrants, say, of zinc and copper. I have noted a very different manifestation of contact electricity presented by this form of electrometer. Let us suppose that the needles and the cells are maintained at a difference of potential of, say, 100 volts, this instrument before you is adapted to work at potentials of from 80 to 120 volts. If the needles were polished aluminium and the cells polished aluminium, we should have none of the difference due to contact electricity. You get apparently 100 and $\frac{1}{10}$ ths or 100 $\frac{1}{10}$, when the needles are positive and the cells negative; on the other hand, when the needles are negative and the cells positive, you get 99 $\frac{9}{10}$, the mean being correctly 100 volts. I anticipated this when the instrument was first made, but our first trials of all first instruments within the year of preparation showed such effect to a degree so little that it could barely be perceived. You could barely see $\frac{1}{10}$ th of a volt difference. We made more than a year ago a great many careful experiments, and never found more than $\frac{1}{10}$ th of a volt. Quite lately my attention was recalled to this by my former assistant, Mr. Rennie, now of the Board of Trade testing laboratory which has lately been established under the superintendence of Major Cardew. He found, with a new instrument recently supplied to that laboratory, a larger difference of just about the

amount we originally expected. I have tried new instruments since, and found it much greater than in the earlier trial instruments. The explanation is, that in the original instruments that were made for trial, with pieces of metal that had been tossed about in the laboratory, and with needles and plates unpolished, the condition of surface was not such as to give the proper difference. But in the finished instruments, with a high polish a definite difference of this kind, much greater than in the original trial instruments, was obtained. I received a letter this morning from Mr. Rennie about experiments on an electrometer at the Board of Trade.

In the course of these experiments at the Board of Trade, extending over a month or six weeks, and made at frequent intervals, there were doubled differences amounting from '5 to '6. There was evidence of a slight decrease in the error, and it is not at all improbable that in time this error may diminish when the initial state of polish may have become toned down. I made one experiment of that kind, subjecting an instrument, just as it stood, both cells and needles, to damping by vapour of water; but the result was not to diminish the difference, but rather to augment it. But exceedingly little change takes place. The explanation is, of course, that polished aluminium is positive to brass, just as zinc is positive to brass, and the effect is of the same kind as would be observed if we had zinc needles and copper cells, the form of contact electricity with which we are most familiar. Let us suppose, instead of being connected to a battery, a metallic connection is made between the cells and the needles; then we shall have a simple contact difference between aluminium and brass. A direct experiment on the force due to that would show no result. Let us say 1-volt is the difference.

The force due to this difference when the terminals are metallically connected bears to the force due to it, when a difference of 100 volts is maintained between them, the ratio of $(\frac{1}{100})^2$ to $(100 + \frac{1}{100})^2 = 100^2$, or, approximately, 1 to 800.

SECONDARY CELLS.

By W. J. S. BARBER STARKEY.

(Read before Section G, September 8th, 1890.)

I SHALL only try to give a few of my personal experiences with secondary cells without attempting to go into their theory or construction, and I do this more in the hope that it may lead to some interesting discussion, than for any value which may be attached to my experiences. Soon after the introduction of M. Faure's cells into this country I was fortunate enough to become possessed of one, which for a time gave excellent results, but it so happened I had to go away from home for six months, and on my return I found the cell would no longer work satisfactorily, and had become very inefficient.

To find out the cause of this I removed the plates from their felt envelopes, and found that they were partially covered with a white hard sulphate of lead, which I was unable again to reduce; I also found that it had eaten into the supporting plates, and that there was a thin film of white sulphate between these plates and the active material, which practically acted as a non-conductor. This seemed to me such a serious defect that I determined if possible to find out a remedy, and, after numberless ineffectual attempts, I at last found out that if a small quantity of carbonate of soda was added to the dilute acid, it not only allowed the existing sulphate to be again reduced, but it also prevented the formation in future of the hard white intractable sulphate, even if the cells were allowed to stand idle for any length of time. I have allowed plates to remain idle in this solution for more than 18 months, without the slightest trace of white sulphate appearing. Five years ago next Christmas, a small installation consisting of twenty-two E.P.S. 350 ampere-hour cells was fitted up for me, and it so happened that the dilute acid was by mistake put into the accumulators a considerable time before the engine was ready to run, by which time the plates showed signs of sulphating, and as I had only a small current of 10 amperes at my disposal, I was not able again to bring the plates to their proper state, and the sulphating became worse and worse, till all the plates presented a dull grey appearance. I showed them to several electrical experts, and the opinion was that they were ruined, and the only suggestion was that I should pass a heavy current for a long time through the cells. This I was unable to do with the power at my disposal, but I passed a current of 10 amperes continuously through them for a week without the slightest apparent results. Seeing this treatment was hopeless, I then determined to try the carbonate of soda which I had used on a small scale some years previously on the Faure cell. I was told that I should probably ruin the cells, so I began cautiously. Into one cell out of the twenty-two I put a small quantity of carbonate of soda (ordinary washing soda), and I then went on charging as before, and before many hours had elapsed I was delighted to see that the plates in the cell, to which carbonate of soda had been added, were beginning to assume their proper appearance, the positive plates becoming a very dark brown peroxide, and the negative plates a clear metallic lead, which was a great contrast to the uniform dull grey appearance of all the plates in the other cells. As soon as I was convinced that the treatment with carbonate of soda was satisfactory, I added it to all the other cells, with the result that in a short time every trace of the formerly intractable white sulphate disappeared, and the cells presented a beautiful appearance. It is now nearly five years since the cells were thus treated, and

they have never since shown signs of sulphating, and are apparently in as good condition now as when new. I was so much impressed with the use of carbonate of soda to prevent sulphating of the plates, that I brought the matter before Mr. Preece, and he very kindly came to look at the cells, and afterwards carried out a most careful series of experiments to determine the value or otherwise of using sulphate of soda in secondary cells. The results of these experiments are, I believe, well known, and have been published, and the exact amount of carbonate of soda which it is desirable to use has been determined: it is only necessary to use a very small quantity to effect the desired purpose. If much is used it is of no advantage, and may tend to cause scaling of the plates. Now that it is no longer necessary to pass a heavy current through cells, to prevent sulphating, it appears to me that it would be much more satisfactory to use larger cells for stationary work, and both charge and discharge them at a considerably lower rate than at present recommended, thereby enormously increasing the life and efficiency of the cells, and leaving a large surplus of energy in case of emergency. My own cells have been treated in this way, and I cannot see that they have in any way deteriorated after nearly five years' use. If the plates are kept free from sulphate, they may be bent to a considerable extent without suffering any damage, and if the grids are made of pure soft lead they may be readily straightened again. Certainly my experience leads me to recommend the use of soft lead grids in preference to those of a hard and brittle alloy. I consider that burning the lugs together is the most satisfactory way of connecting up the cells, but if brass screws and nuts are used they can be greatly protected by pressing some lead foil over and around them, this will keep off any acid spray which might reach them while the cells are being charged, and should any of the brass connections become corroded, I have found that they can be effectually cleaned without trouble by immersing them for a time in a solution of carbonate of soda, and then washing them thoroughly in pure water. If it is desired to use separators between the plates, a very simple and cheap way to make them is to use perforated porous paper which has been saturated in melted paraffin wax, this stands well in dilute acid, and I have some which have been in use for several years.

Although secondary batteries are now undoubtedly very efficient when carefully used for stationary purposes, it appears to me that as at present constructed they will not stand for any long period the wear and tear, shaking and washing of the liquid against the active material to which they must be subjected when used for traction purposes; at least such is the impression left on my mind after inspecting cells which have been used for even a short time; some of the plates generally soon show signs of buckling, and the bottoms of the cells became covered with disintegrated particles of the active material, which forms a sort of mud. I have endeavoured to overcome these defects by packing the plates in a solid though porous mass of plaster of Paris mixed with sawdust, and for three months a battery of 96 cells thus prepared was successfully running a tramcar at Canning Town and doing the same work as the other cars, however, at the end of this time the management passed into other hands, and I hear that the cells have been taken to pieces, as they were not giving satisfaction, so for the present this experiment has come to an end, and is apparently a failure, but I have not given up hopes that some modification of this plan may be successful, as for a time the working was very satisfactory. The proportion of plaster of Paris used in this experiment was two of plaster of Paris to one of sawdust, but I think the plaster of Paris was not pure, and its proportion was too great. I am now using a set of 22 Elwell-Parker cells, in which the proportion is $2\frac{1}{2}$ of sawdust to 1 of plaster of Paris. The way I prepare the cells is to mix the plaster of Paris and sawdust intimately together in a dry state, and fill in the spaces between the plates with this mixture. I then pour in gently some dilute sulphuric acid to which a little carbonate of soda has been added, when the whole sets into a compact porous mass. After a time I pour in the electrolyte till it stands above the level of the tops of the plates, and it will be found that the cells will contain nearly as much liquid as if no porous material were used.

Last autumn I used a set of these cells in conjunction with a turbine and dynamo, and although they were last charged in November, I found on my return this year in June that they still retained the charge well after seven months' rest, and burnt the lamps brightly, the E.M.F. of each cell being just under 2 volts. Although in my experiments I have used plaster of Paris to insulate the particles of sawdust from each other, and to give stability to the porous mass, I have tried many other substances, both soluble and insoluble, mixed with it, but sawdust appears to act as well as anything which I have yet tried, and it has the advantage of being cheap, and easily procurable. This method of treating the cells would appear to be of no advantage in stationary work for electric lighting purposes, and would indeed be a distinct disadvantage, as owing to the want of free circulation of the liquid, the E.M.F. falls more rapidly under a long-continued heavy discharge, but it immediately recovers with a short interval of rest, and, in practice, these intervals are constantly occurring in electric traction, when the car stops to take up and set down passengers, and with cells treated in this way the vibration and shaking of the car is a positive advantage, as it facilitates the circulation of the electrolyte, and tends to liberate any occluded gases. The defect of this arrangement would appear to be that it must hinder the free circulation of the liquid and also add to the internal resistance of the cell, whilst, on the other hand, it prevents the plates from buckling, retains the active material firmly in its place, preserves the plates from injury, and

makes the cell very portable. I have ventured to mention this crude experiment in the hope that it may induce someone to produce a thoroughly practical cell for traction purposes which will stand rough usage and be free from the defects which at present exist.

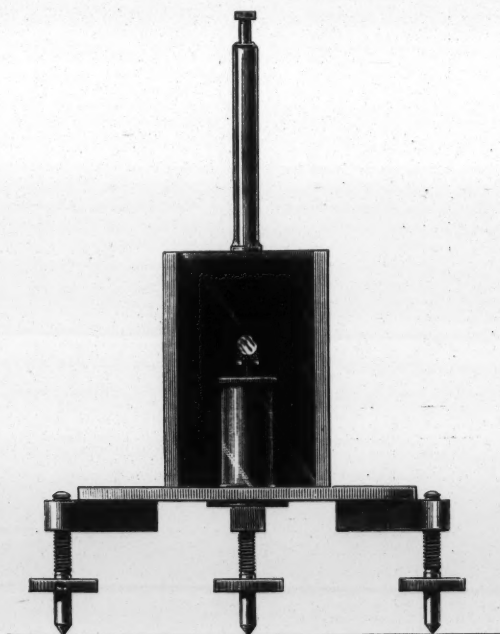
As regards the use of carbonate of soda in secondary cells, a case has just been brought to my notice which appears worthy of mention. I am told that at the Central News office, Ludgate Hill, 28 L. 13 cells had been lying dry and idle for upwards of two years, and each plate was encrusted with hard white sulphate: with ordinary dilute sulphuric acid and a charging current of 10 to 15 amperes, no difference was seen after two charges of eight hours per day; after adding about half a pint of strong carbonate of soda solution to the dilute sulphuric acid in the cells and doing the same electrical work as before, the plates were observed to change colour in a few hours, and in a few days each of the cells presented a beautiful appearance, not a single plate buckled, and I am told that the battery is working perfectly now. This entirely confirms my experience. After plates have been brought to a good condition by the use of carbonate of soda, the ordinary dilute sulphuric acid may be substituted for the mixed electrolyte if the cells are to be used for continuous work; but I believe a small amount of sodium salt is always beneficial; it, however, only becomes a necessity where cells have to stand idle for long periods.

ON THE CHARACTER OF STEEL USED FOR PERMANENT MAGNETS.

By W. H. PREECE, F.R.S.

(Read before Section A, September 9th, 1890.)

In the discussion which followed the reading of Dr. John Hopkinson's Presidential address to the Institution of Electrical Engineers, I took the opportunity to point out that the quality of magnetic steel in England had deteriorated, and that it was not to be compared with that produced in France in 1881. This statement was questioned at the time, and I determined to make an exhaustive test of the various steels that are now in the market. Specimens were therefore obtained from the leading firms in Sheffield, viz., Messrs. Joseph Ashforth and Company, Messrs. Sanderson Bros. & Co., Messrs. Thos. Jowitt and Sons, Messrs. Vickers, Sons & Co., and Mr. G. P. Wall, and also from the following manufacturers in France: M. Marchal and M. Clemandot. Mr. Webb, of Crewe, also gave me some samples of the steel used in those works.



MAGNETOMETER.

The magnetometric method has been followed throughout this enquiry. Square bars, approximately 10 cm. long and 1 sq. cm. in section, were chosen as test pieces in preference to the long wires, ellipsoids, or other special forms of magnet usually employed in very accurate investigations. These bars are comparable in dimensions with the magnets actually employed for telegraphic purposes; they are very convenient for use with the magnetometer, they can be kept in a relatively small compass for periodical testing, and they enable us to compare the magnetic qualities of different steels with very great accuracy. Although they can only be regarded as approximately solenoidal, and are much too short for theoretical exactness, yet it is believed that the values of the induction, intensity of mag-

netisation, and specific magnetism, calculated from the magnetic moments of the various specimens, are sufficiently accurate to be of scientific interest. In order to facilitate calculation, it was desirable that the bars should be exactly 10 cm. long, by 1 sq. cm. in section, but it was found that the specimens received could not be worked to this size. I have therefore determined their dimensions and weights by careful measurements, and have given the details in the subjoined tables.

All the English specimens were carefully and uniformly tempered in water in accordance with our usual practice. Of the four magnets made of Allevard steel two were tempered in water, and two in mercury. The Clemandot compressed steel and the Marchal magnets were already tempered and magnetised when received from Paris.

For magnetising the bars a powerful electromagnet (of a form suggested by Prof. Perry) was employed (fig. 1).

The coil of the electro-magnet is wound with 138 turns of .508 c.m. copper wire, the length of the coil between the cheeks being 9.3 cm. The soft iron core is 10 cm. long and 3 cm. in diameter, and the pole-pieces are 11.5 cm. long and 3 cm. square. The upper pole-piece (which may be removed and replaced by one of a form suitable for maximum induction experiments) is furnished with a thumb-screw and a small movable block, so that the bars to be magnetised may be clamped in position, care being taken that their ends make perfect contact with the pole-pieces.

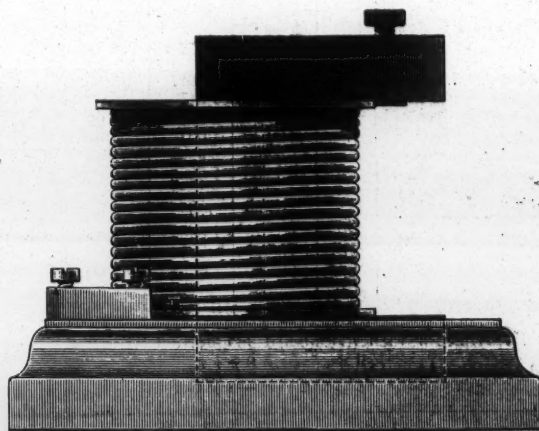
In the first series of experiments the magnetising current employed was 100 amperes (13,600 ampere-turns), and it was kept on for 30 seconds for each bar.

In the second series the current was increased to 325 amperes (41,200 ampere-turns), and kept on for three seconds in each case. Generally speaking this increased current did not increase the permanent magnetisation of the bars; but, on the contrary, the magnetisation was, in most cases, apparently slightly less than it was after magnetisation with 100 amperes three months previously. The magnetisation of the Clemandot and Marchal magnets was, however, considerably increased by the same treatment, as will be seen from the tabulated result of the experiments.

The magnetometer employed is simply a Thomson mirror, suitably mounted with levelling screws, and placed over the centre of a millimetre scale two metres long. The scale for reading the deflections is of the usual straight kind with central zero, and is placed at a constant distance of 100 cm. from the mirror. The magnets were, in most cases, tested with their centres at distances of 100 and 75 cms. from the mirror, and the mean of readings on either side of zero in each position was taken. The moments have been

calculated from the formula: $M = \frac{H(r^2 - l^2)}{2} \tan \theta$; r being the distance of the magnet from the mirror, and l half the length of magnet (= 5 cms. very nearly).

The maximum value of 2θ being only about 4° , $\tan \theta$ has been taken as equal to $\frac{\tan 2\theta}{2}$.



MAGNETISING ELECTROMAGNET.

The value of H for the room in the General Post Office in which the first series of experiments were made was determined both by the coil method and by the method of vibrations.

1. Experiments with a coil of 18 turns, and a mean radius of (15.6) cms.:-

Date.	Current.	Distance of coil from mirror.	Deflection.	Tan. θ	H.	Mean value of H.
	Ampères.	mm.	mm.			
June 12th...	5	1,000	21.01	.01047	1268	1276
" " " "	53	600	96.14	.04803	1275	
" 15th ..	5	1,000	20.93	.01046	1269	
" " " "	47	750	44.79	.0224	1285	
" " " "	44	600	79.53	.03965	1282	

TABLE I.

RESULTS OF EXPERIMENTS FOR DETERMINING THE MAGNETIC MOMENTS, &c., OF VARIOUS KINDS OF STEEL.
First Series.—June, 1890.

Name of manufacturer.	No. of specimen.	Weight.	Mean area of poles.	Length.	Volume.	Mean moment. M.	Specific magnetism.	Intensity of magnetisation (I)	Induction (4 π I)	Mean induction of specimens made from each kind of steel.	Remarks.
		Grammes.	Sq. cm.	c.m.	cub. cm.						
Wall ...	1	67·279	·8503	10·025	8·525	985·4	14·65	115·6	1452	1524	Steel splits in tempering.
	2	67·235	·8513	10·04	8·547	962·0	14·31	112·6	1414		
	3	66·252	·8446	10·02	8·463	1032·5	15·53	120·8	1517		
	4	66·648	·8487	10·01	8·496	1158·5	17·38	136·4	1713		
Ashforth ...	1	75·228	·9295	10·00	9·295	1380·5	18·35	148·5	1866	1710	
	2	76·265	·9436	10·00	9·436	1274·5	16·71	135·1	1697		
	3	75·870	·9365	10·00	9·365	1101·5	14·52	117·6	1478		
	4	76·247	·9398	10·03	9·426	1348·8	17·69	143·1	1798		
Saunderson ...	1	77·962	·9712	10·04	9·750	1258·4	16·14	129·1	1622	1444	One specimen split slightly in tempering.
	2	77·800	·9740	10·03	9·770	1051·0	13·51	107·6	1351		
	3	76·955	·9645	10·03	9·674	1048·7	13·63	108·4	1362		
	4	77·145	·9634	10·03	9·662	1107·8	14·36	114·7	1441		
Jowitt ...	1	73·928	·9186	10·04	9·222	972·0	13·15	105·4	1324	1522	
	2	74·120	·9249	10·03	9·276	1303·7	17·59	140·5	1766		
	3	72·058	·8995	10·03	9·022	1010·8	14·03	112·0	1407		
	4	73·840	·9214	10·03	9·241	1170·9	15·86	126·7	1592		
Vickers ...	1	68·631	·8811	10·04	8·846	792·1	11·54	89·54	1125	1158	One specimen failed to stand tempering, one slightly split.
	2	70·043	·9010	10·03	9·037	934·9	13·35	103·5	1300		
	3	66·651	·8589	10·02	8·606	718·7	10·78	83·52	1049		
Crewe "rivet steel"	1	75·751	·9731	9·98	9·711	149·6	1·97	15·40	193·5	180·6	
	2	75·820	·9790	9·97	9·760	162·3	2·14	16·63	208·9		
	3	75·553	·9736	9·97	9·706	149·6	1·98	15·41	193·6		
	4	77·210	·9909	10·00	9·909	99·88	1·29	10·08	126·6		
Crewe "spring steel"	1	75·012	·9763	10·02	9·783	1093·3	14·58	111·7	1404	1364	Two specimens failed to stand tempering; other two badly split.
	2	76·086	·9837	10·02	9·857	1039·0	13·65	105·4	1324		
Clemandot ...	A1	79·518	—	9·90	9·914	872·9	10·98	88·07	1106	1116	These bars are of compressed steel, tempered and magnetised by the maker; they are rather roughly finished and their dimensions could only be approximately determined. Tested as received from Paris.
	2	80·335	—	9·95	10·04	968·6	12·06	96·48	1212		
	3	80·208	—	9·98	10·03	956·9	11·93	95·41	1199		
	4	79·94	—	9·96	9·993	1127·1	14·10	112·8	1417		
	5	80·542	—	9·97	10·07	1010·8	12·55	100·4	1261		
	6	79·958	—	9·96	9·995	1284·1	16·06	128·5	1614		
	B7	80·322	—	9·88	10·04	741·2	9·227	73·83	928	928	Compressed, but untempered.
Marchal ...	1	78·478	·9917	10·00	9·917	1750·7	22·31	176·5	2218	1839	Tempered and magnetised by the maker. Tested as received from Paris.
	2	80·253	1·011	10·00	10·106	1556	19·39	154·0	1934		
	3	79·380	1·014	10·00	10·136	1372	17·28	135·4	1701		
	4	79·540	1·001	10·00	10·01	1645	20·68	164·3	2065		
	5	78·260	·9992	10·00	9·992	1200·5	15·34	120·1	1510		
	6	79·488	1·0006	10·00	10·006	1279·8	16·10	127·9	1607		
"Allevard" ...	1	79·900	·9996	9·86	9·856	878·9	11·00	89·17	1120	1318	Tempered in mercury.
	2	80·415	1·0064	9·87	9·934	1199·4	14·92	120·7	1517	1664	Tempered in water.
	3	79·600	·9944	9·89	9·835	1480·5	18·60	150·5	1892		
	4	79·765	1·0054	9·90	9·954	1138·6	14·27	114·4	1437		

2. Experiments with glass hard magnetised wires.—A calculated from the formula, $H^2 = \frac{8 \pi r K}{T^2 (r^2 - l^2)^2 \tan \theta}$.

Date.	Moment of inertia K.	r.	Deflect.	Tan. θ	Time of complete vibration, T.	H.	Mean.
June 15th.							
No. 1 wire.	5·6421	400	17·58	·00879	7·075	·1278	1·277
2 "	5·574	"	12·14	·006069	8·462	·1278	
3 "	5·574	"	17·48	·008738	7·062	·1276	

The values of H thus obtained, although agreeing closely with each other, being surprisingly low, the same wire magnets were taken to a spot 4 or 5 miles from the G.P.O., and it was then found that their periods of vibration were reduced respectively to 5·99, 7·14, and 5·95 seconds, making H about 1782, and showing that the previous determinations were fairly accurate.

During the second series of experiments the following values of H were obtained by the coil method:—

Date.	Current ampere.	Distance of coil from mirror.	Mean deflection.	Tan. θ	H.	Mean value of H.
Aug. 23	...	mm.	mm.			
" 23	·48	1,000	20·09	·010045	·1269	1280
" 23	·47	750	44·37	·022185	·1297	
" 24	·455	"	42·70	·021350	·1269	
" 24	·44	"	41·86	·02093	·1287	

Taking the strongest magnets of each group in the second series of experiments, and arranging them in order, we have—

	Induction.
Marchal, No. 1	2,835
Clemandot, No. 1	2,362
" Allevard," No. 3 (water tempered)	1,879
Ashforth, No. 4	1,779
Jowitt, No. 2	1,745
Wall, No. 4	1,689
Saunderson, No. 1	1,610
" Allevard," No. 2 (mercury tempered)	1,528
Crewe "spring," No. 1	1,436
Vickers, No. 2	1,297
Crewe "rivet," No. 3	217

TABLE II.

RESULTS OF EXPERIMENTS FOR DETERMINING THE MAGNETIC MOMENTS, &c., OF VARIOUS KINDS OF STEEL.

Second Series.—August, 1890.

Name of manufacturer.	No. of Specimen.	Weight.	Mean area of pole.	Length.	Volume.	Mean moment.	Specific Magnetism.	Intensity of magnetisation (I).	Induction (4 π I) B.	Mean Induction of specimens made from each kind of steel.	Remarks.
		Grammes.	Sq. cm.	cm.	cub. cm.						
Wall	1	67·279	·8503	10·023	8·525	1003·5	14·91	117·7	1479	1519	
	2	67·235	·8513	10·04	8·547	946·4	14·08	110·7	1391		
	3	66·252	·8446	10·02	8·463	1022	15·42	120·7	1517		
	4	66·648	·8487	10·01	8·496	1142	17·13	134·4	1689		
Ashforth	1	75·228	·9295	10·00	9·295	1258	16·72	135·3	1700	1704	
	2	76·265	·9436	10·00	9·436	1264	16·57	133·9	1682		
	3	75·870	·9365	10·00	9·365	1103	14·54	131·9	1657		
	4	76·247	·9398	10·03	9·426	1334·5	17·50	141·6	1779		
Saunderson	1	77·962	·9712	10·04	9·750	1249	16·02	128·1	1610	1435	
	2	77·800	·9740	10·03	9·770	1054	13·55	107·9	1356		
	3	76·955	·9645	10·03	9·674	1036	13·46	107·1	1346		
	4	77·145	·9634	10·03	9·662	1099	14·24	113·7	1429		
Jowitt	1	73·928	·9186	10·04	9·222	968	13·09	104·9	1319	1503	
	2	74·120	·9249	10·03	9·276	1288	17·35	138·8	1745		
	3	72·058	·8995	10·03	9·022	998	13·85	110·6	1390		
	4	73·840	·9214	10·03	9·241	1147	15·53	124·1	1560		
Vickers	1	68·630	·8811	10·04	8·846	815	11·88	92·12	1158	1174	
	2	70·043	·9010	10·03	9·037	933	13·32	103·2	1297		
	3	66·651	·8589	10·02	8·606	730	10·45	84·82	1066		
(Crewe "rivet steel")	1	75·751	·9731	9·98	9·711	157	2·072	16·16	203	186·6	
	2	75·820	·9790	9·97	9·760	151	1·991	15·47	194		
	3	75·553	·9736	9·97	9·706	167·5	2·217	17·26	217		
	4	77·210	·9909	10·00	9·909	104·5	1·353	10·84	132·5		
Crewe "spring steel"	1	75·012	·9763	10·02	9·783	1118·5	14·91	114·3	1436	1391	
	2	76·086	·9837	10·02	9·857	1056	13·88	107·1	1346		
Clemandot	A1	79·518	—	9·90	9·914	1864	23·44	188·0	2362	2265	Mean induction increased by 103 per cent. over its original value by remagnetisation in our coil.
	2	80·335	—	9·95	10·04	1797·5	22·37	179·0	2250		
	3	80·208	—	9·98	10·03	1783	22·22	177·8	2234		
	4	79·94	—	9·96	9·993	1786	22·34	178·7	2245		
	5	80·542	—	9·97	10·07	1738	21·58	172·6	2169		
	6	79·958	—	9·96	9·995	1853	23·17	185·4	2329		
	B7	80·322	—	9·88	10·04	1065	13·26	106·1	1333		
Marchal	1	78·478	·9917	10·00	9·917	1671·5	21·30	168·5	2118	1758	Before re-magnetisation.
	2	80·253	1·011	10·00	10·106	1495	18·63	148·0	1859		
	3	79·380	1·014	10·00	10·136	1304	16·43	128·6	1616		
	4	79·540	1·001	10·00	10·01	1565	19·68	156·3	1964		
	5	78·260	·9992	10·00	9·992	1135	14·50	113·6	1427		
	6	79·488	1·0006	10·00	10·006	1246	15·68	124·5	1565		
Marchal	1	78·478	·9917	10·00	9·917	2237	28·50	225·6	2835	2540	After remagnetisation. Mean induction increased by 38 per cent. over its original value.
	2	80·253	1·011	10·00	10·106	2221	27·67	219·8	2761		
	3	79·380	1·014	10·00	10·136	1842	23·20	181·7	2283		
	4	79·540	1·001	10·00	10·01	2147	26·99	214·5	2695		
	5	78·260	·9992	10·00	9·992	1845	23·57	184·6	2320		
	6	79·488	1·0006	10·00	10·006	1868	23·50	186·7	2346		
"Allevard"	1	79·900	·9994	9·86	9·856	865	10·83	87·76	1103	1315	
	2	80·415	1·0064	9·87	9·934	1208	15·02	121·6	1528		
	3	79·600	·9944	9·89	9·835	1471	18·48	149·5	1879		
	4	79·765	1·0054	9·90	9·954	1142	14·31	114·7	1442		

If we take the mean induction of the magnets of each group, which is probably a fairer method of comparison, we obtain a slightly different order, viz.:

	Mean Induction.
Marchal	2,540
Clemandot	2,265
Ashforth	1,704
Allevard (water tempered)	1,660
Wall	1,519
Jowitt	1,503
Saunderson	1,435
Crewe "spring"	1,391
Allevard (mercury tempered)	1,315
Vickers	1,174
Crewe "rivet"	186·6

The marked superiority of the Marchal magnets over those made of English steel is evidently not due to the method of magnetisation adopted by the maker, since their mean induction was increased by 38 per cent., and their magnetisation rendered more uniform by re-magnetisation in our coil. Their greater strength must therefore be due either to the quality of the steel, or to the

mode of tempering—most probably the latter. The Clemandot compressed steel magnets, too, which were very poor when first tested, had their mean induction more than doubled by re-magnetisation.

In view of the results of these experiments, I purpose to investigate further the methods of tempering magnet steel. It is pretty clear there is room for improvement in our present practice.

I am indebted to M. Trotin, of the French Telegraphic Administration, for having kindly procured the French specimens for me.

The induction in these short straight bars is comparatively low, because we measure only the lines (Maxwell's B) that radiate from the ends. Prof. Perry has succeeded in getting as much as 12,700, with Jowitt steel, through the middle of a magnet of a special horseshoe form. It ought, apparently, to be possible to get about 20,000 with the best French steel.

I happen to have in my possession two small horseshoe magnets of Allevard steel which were made for Mr. H. Edmunds, and magnetised in Paris in 1881. The induction of one is now 3,287·3, and of the other 3,552·5. They have never been touched since 1881. The retentiveness is therefore very good.

All these measurements have been made with great patience and skill by Mr. Henry Hartnell.

ON ANTI-EFFECTIVE COPPER IN PARALLEL CONDUCTORS OR IN COILED CONDUCTORS FOR ALTERNATE CURRENTS.

By Sir WM. THOMSON.

(Read Before Section A, September 5th, 1890.)

1. It is known that by making the conductors of a circuit too thick, we do not get the advantage of the whole conductivity of the metal—copper, let us say—for alternate currents. When the conductor is too thick, we have in part of it comparatively ineffective copper present; but, so far as I know, it has generally been supposed that, the thicker the conductor, the greater will be its whole effective conductance, and that thickening it too much can never do worse than add comparatively ineffective copper to that which is most effective in conveying the current. It might, however, be expected that we could get a positive augmentation of the effective ohmic resistance, because we know that the presence of copper in the neighbourhood of a circuit carrying alternate currents, causes a virtual increase of the apparent ohmic resistance of the circuit, in virtue of the heat generated by the currents induced in it. May it not be that, anti-effective influence, such as is thus produced by copper not forming part of the circuit, can be produced by copper actually in the circuit if the conductor be too thick? Examining the question mathematically, I find that it must be answered in the affirmative, and that great augmentation of the effective ohmic resistance is actually produced if the conductor be too thick; especially in coils consisting of several layers of wire laid over one another in series around a cylindric or flat core (as in various forms of transformers).

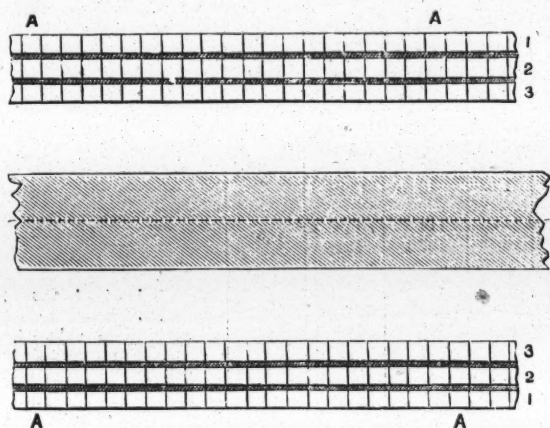


FIG. 1.

2. Fig. 1 may be imagined to represent the secondary coil of a transformer consisting of solid square copper wire in three layers. For simplicity, we suppose the axial length to be infinitely great, and straight; but the uniformity which this involves, and a close practical application to its simplicity is realised in that excellent form of transformer which consists of a toroidal iron core completely covered by primary and secondary wires laid on toroidal surfaces. To simplify the mathematical work, I suppose the whole thickness of the three layers to be small in comparison with the greatest radius of curvature of the circular or flat cylindric surface on which the wire is wound, but if it is not so the solution is easily obtained, for the case of circular cylinders, in terms of the Fourier-Bessel functions. It is of no consequence for our present question what there be inside of coil No. 3, and if we please we may imagine there to be nothing but air; the drawing, however, indicates an iron core and space which might be occupied by the primary coil, if a transformer is the subject; or our coil, A, A, A, A, may be the primary coil of a transformer with secondary coil and core inside it, and the alternate current maintained in it by an external electromotive agent acting in an arc between its ends outside. Our present results are applicable to all these varieties of cases indifferently, all that is essential being that the total quantity of current be given at each instant, and be uniform throughout the whole length of the coiled conductor.

3. This last condition is secured by perfectness of insulation between all contiguous turns of the coil, unless we were considering so enormously long a coil that the quantity of electricity required for the essential changes of static electrification would be sensible as constituting drafts from, or contributions to, the current in the coil. The consideration of static electrification involved in the maintenance of alternate currents through a coil such as that represented in fig. 1, is exceedingly curious and interesting; but we do not enter on it at present at all, as in all practical cases the quantities concerned are quite infinitesimal in comparison with the whole quantity flowing in one direction or the other in the half period.

4. In the drawing, the section of the wires is represented as square, but this is not essential, and in practice a flat rectangular

ribbon would, no doubt, for some dimensions of coils, be preferable. I assume the thickness of the insulation between the successive squares or rectangles in each layer to be infinitely small in comparison with the breadth of the rectangle; but the thickness of the insulation between successive layers, which is a matter of indifference to my calculations, may be anything, and would in practice naturally be, as shown in the diagram, considerably greater than the thickness of the insulation between the contiguous portions of the coil in each layer.

5. The full mathematical work which I hope to communicate to the *Philosophical Magazine* for publication in an early number, includes an investigation of the self-induction of the coil, with or without anything in its interior (such as core, or primary wire of a transformer), but, at present, I merely give results so far as effective ohmic resistance, or generation of heat in the interior of the wire of the coil, A, A, A, A, itself is concerned; which, as said above, is independent of everything in the interior, and of the mode in which the alternating current is produced, provided only that the total amount of electricity crossing the section of the wire per unit of time be given at each instant.

6. As a preliminary to facilitate the expression of these results, it is convenient first to give a general statement of the solution of the problem of laminar diffusion of a simple harmonic variation, applied to the case of electric currents in a homogeneous conductor. Let the periodically varying magnetic force in the air or other insulating material in the neighbourhood of so small a portion, s , of the surface of a conductor that we may regard it as plane be given. Resolve this magnetic force into two components, one perpendicular to s which we may neglect, as it has no influence in connection with the currents we are to consider; the other parallel to s , which we shall call the effective component, and denote by x . Through any point, o , of s , draw three rectangular lines, ox , oy , oz , of which oy and oz are in s , and ox is parallel to the direction of the effective magnetic force component, x . Let now the value of y at time, t , be

$$y = M \cos \frac{2\pi t}{T},$$

where M denotes a constant, and T the period of the alternation. The varying magnetic force, z , whatever cause it may be due, gives rise to currents parallel of oz in the conductor, expressed by the following formula for γ , the current intensity at distance, x , from the plane, s , provided x be small enough to fulfil the condition stated below:—

$$\gamma = \frac{M}{\lambda \sqrt{2}} e^{-\frac{2\pi x}{\lambda}} \cos \left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \frac{1}{4}\pi \right),$$

where λ denotes what we may call the wave length of the disturbance and is given in the terms of T , the period of the disturbance, and ρ and ω the resistivity and magnetic permeability of the substance, by the following formula:—

$$\lambda = \sqrt{\frac{T\rho}{\omega}}.$$

For copper we have $\omega = 1$, and $\rho = 1611$ square centimetres per second; and thus for 80 periods per second $\lambda = 4.49$ or, say, $4\frac{1}{2}$ centimetres.

In order that the formula for γ may be approximately true, it is necessary, in the first place, that λ must be small in comparison with the distance we must travel in any direction in the surface of s , before finding any deviation of it from the tangent plane through o , comparable with λ . Secondly, for a very good approximation, λ must be so small that we may be able to travel inwards, in any direction from o , through a space equal to at least twice λ , without coming to any other part of the bounding surface of the conductor. If, for example, the surface be a flat plate, this condition requires that the thickness be more than twice λ . But (because $e^{-\pi}$ is less than $1/23$), the formula gives a very fair approximation, requiring for a half the thickness of the plate inwards from s no greater correction than about 4 per cent, even if the thickness of our plate be no greater than λ . When the thickness of the plate is less than 2λ , we may consider waves of electric current as travelling inwards from its two sides and being both sensible at the middle of the plate; and a complete solution of the problem is readily found by the method of images. But, a direct analytical investigation, by which the proper conditions of relation to varying magnetic force on the two sides of the plate are fulfilled is the most convenient way of fully solving the problem, and it is thus that the results given below have been obtained.

7. The smallness of the insulating space between the successive turns in each layer of our coil A, A, A, A, and the equality of the whole current through them all, prevent any surface disturbance from being produced at the contiguous faces, and allow the problem to be treated as if, instead of a row of squares or rectangles we had a continuous plate forming each stratum. The smallness of the thickness of this plate in comparison with the radius of the cylindric surface to which it is bent, allows, as said above, the mathematical treatment for an infinite plate bounded by two parallel planes to be used without practical error. I have thus found an expression for the intensity of the current at any point in the metal of any one of the layers of a coil of one, two, three, or more layers; and have deduced from it an expression for the quantity of heat generated per unit of time, at any instant, per unit breadth in any one of the layers. I need not at present quote the former expression; the latter is as follows. With q to denote

the dynamical value in time average of the heat generated, per unit of time at different instants of the period, per unit breadth and unit length in layer No. i from the outside of the coil, c^2 the time average of the square of the total current per unit breadth, and a the thickness of the layer

$$q = \frac{2\pi\rho}{\lambda} \Theta c^2$$

$$\text{where } \Theta = \frac{\epsilon^{2\theta} + 2 \sin 2\theta - \epsilon^{-2\theta}}{\epsilon^{2\theta} - 2 \cos 2\theta + \epsilon^{-2\theta}} + 2i(i-1) \frac{\epsilon^{\theta} - 2 \sin \theta - \epsilon^{-\theta}}{\epsilon^{\theta} + 2 \cos \theta + \epsilon^{-\theta}}$$

$$\text{and } \theta = \frac{2\pi a}{\lambda}$$

8. The numerical results shown in the table have been calculated, and the accompanying graphic representation (fig. 2), drawn, for me by Mr. Magnus Maclean.

TABLE OF VALUES OF Θ .

$\frac{16\theta}{\pi}$	$i = 1$	$i = 2$	$i = 3$	$i = 4$
1	5.113	5.118	5.127	5.141
2	2.553	2.592	2.669	2.786
4	1.316	1.634	2.270	3.224
6	.9854	1.997	4.019	7.053
8	.9173	2.993	7.143	13.37
10	.9452	4.062	10.30	19.65
12	.9822	4.899	12.73	24.48
14	1.000	5.276	13.83	26.66
16	1.002	5.362	14.08	27.16
∞	—	5.00	13.00	25.00

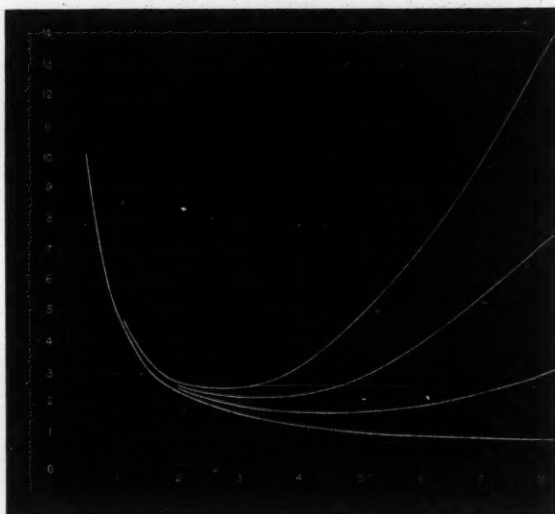


FIG. 2.

8. We see from the table and curves that each curve has a minimum distance from the line of abscissas, and that each comes to a horizontal asymptote, parallel to the line of abscissas, for $\theta = \infty$. By looking at the formula, we see that there is, in fact, an infinite succession of minimums and maximums in the expression for Θ , but it is only the first minimum, and the following maximum, that occur within the range of variation of θ , which we regard as sensible. In the case of $i = 1$, the formula gives $\theta = \frac{1}{2}\pi$ for the first minimum. The curves show for the

case of $i = 2, 3, 4$, respectively, the first minimum at $\frac{16\theta}{\pi} = 4\frac{1}{2}, 3$, and 2.6 , respectively. The thickness which corresponds to $\theta = \pi$ is the half wave length of the electric disturbance, which, as we have seen is for copper 2.244 centimetres, when the frequency of the alternations is 80 periods per second; and for this case, therefore, the thicknesses that give minimum generation of heat in the first, second, third, and fourth layers are, respectively, 11.22, 6.31, 4.21, and 3.65 millimetres. Anything more of continuous copper than these thicknesses in any of the layers would be not merely ineffective or comparatively ineffective, but would be positively anti-effective. Even with so small a thickness as 2.8 millimetres, for copper and frequency 80, line 2 of the table (corresponding to a sixteenth of the wave-length) shows, in the first, second, third, and fourth layers, losses of 0.3 per cent., 2 per cent., 5 per cent., and 10 per cent. in excess of that due to the true ohmic resistance of the copper, were it all effective. When the size chosen for the transformer and the amount of output required of it are such that a thickness of $2\frac{1}{2}$ millimetres in the direction perpendicular to the

layers is insufficient, a remedy is to be had by using braided wire, or twisted strand, with slight insulation of varnish or whitewash, crushed or rolled into rectangular or square form of the desired thickness and breadth. A very slight resistance between the different wires thus crushed together would suffice to cause the current to run nearly enough full bore to do away with any sensible loss from the cause which forms the subject of this communication.

ON THE FORM OF SUBMARINE CABLES FOR LONG DISTANCE TELEPHONY.

By W. H. PREECE, F.R.S.

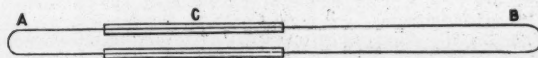
(Read before Section G, September 9th, 1890.)

At the Newcastle meeting last year, I gave the reasons and experiments which led to the conclusion that telephoning between London and Paris was practical. New and distinct aerial lines of four copper wires are now being erected by the respective governments from each capital to the coast, and a new cable, the joint property of the two governments, will be laid during this year, between the Kent coast and Sangatte, to connect these two lines. There will thus be two metallic circuits between the two capitals. The $\kappa \epsilon$, that is the product of the capacity, κ , and the resistance, ϵ , of each circuit, upon which the clearness of articulation depends, will be 5,900, indicating that speech should be excellent.

A somewhat similar circuit has been established, since October last, between Buenos Ayres and Monte Video, under my advice. The cables across the La Plata are each 28 miles long, for there are two separate single wire cables, and the total distance between the two cities is 180 miles. Subscribers, who have metallic circuits in each city, have no difficulty whatever in speaking to each other from their respective offices, although the $\kappa \epsilon$ is as high as 10,400.

The cable across the Channel will be a four-wire cable, and the specification for its construction has been based on the following mathematical development by Mr. H. E. Kempe.

Let there be a looped telephonic line between A and B, with a cable c, at an intermediate point on the route.



The working capacity of the whole line is dependent upon the product of the total resistance, ϵ , and the total capacity κ . Therefore, if we take the resistance of the aerial portion of the line to be a fixed quantity, there will be a particular size of cable conductor which will give the smallest possible size of dielectric, sufficient to enable a particular value of $\kappa \epsilon$ not to be exceeded. For, if we make the conductor larger than this size, and thereby diminish its resistance, we can, it is true, do with an increased capacity, but the diminution in the thickness of the dielectric which could thereby be allowed, is more than compensated for by the fact that the surface of the conductor is larger; in other words, we increase the capacity in a greater proportion than we diminish the resistance. If, on the other hand, we diminish the size of the conductor, we increase the resistance in a greater proportion than we diminish the capacity. Strictly speaking, the requirements of the problem are to determine the size of cable core which shall cost least; but inasmuch as the costs of gutta-percha and copper, bulk for bulk, do not differ greatly, the problem resolves itself into the determination of the smallest outer diameter which can be employed.

Let

$$\begin{aligned} r &= \text{total resistance of aerial line,} \\ \rho &= \text{,, ,, ,, cable,} \\ k &= \text{,, capacity of aerial line,} \\ \kappa &= \text{,, ,, ,, cable.} \end{aligned}$$

Then

$$\kappa \epsilon = (k + \kappa) (r + \rho).$$

Let

$$\begin{aligned} D &= \text{diameter of dielectric of cable,} \\ x &= \text{,, ,, conductor ,, } \end{aligned}$$

Then

$$\rho = \frac{a}{x^2} \text{ and } \kappa = \frac{b}{\log_{\epsilon} \frac{D}{x}}$$

where a and b are constants.

We have, therefore,

$$\kappa \epsilon = \left(k + \frac{b}{\log_{\epsilon} \frac{D}{x}} \right) \left(r + \frac{a}{x^2} \right)$$

therefore

$$\frac{b}{\log_{\epsilon} \frac{D}{x}} = \frac{\kappa \epsilon}{r + \frac{a}{x^2}} - k = \frac{\kappa \epsilon - k \left(r + \frac{a}{x^2} \right)}{r + \frac{a}{x^2}}$$

therefore

$$\log_{\epsilon} \frac{D}{x} = \frac{b \left(r + \frac{a}{x^2} \right)}{\kappa \epsilon - k \left(r + \frac{a}{x^2} \right)}$$

ON ANTI-EFFECTIVE COPPER IN PARALLEL CONDUCTORS OR IN COILED CONDUCTORS FOR ALTERNATE CURRENTS.

By Sir WM. THOMSON.

(Read Before Section A, September 5th, 1890.)

1. It is known that by making the conductors of a circuit too thick, we do not get the advantage of the whole conductivity of the metal—copper, let us say—for alternate currents. When the conductor is too thick, we have in part of it comparatively ineffective copper present; but, so far as I know, it has generally been supposed that, the thicker the conductor, the greater will be its whole effective conductance, and that thickening it too much can never do worse than add comparatively ineffective copper to that which is most effective in conveying the current. It might, however, be expected that we could get a positive augmentation of the effective ohmic resistance, because we know that the presence of copper in the neighbourhood of a circuit carrying alternate currents, causes a virtual increase of the apparent ohmic resistance of the circuit, in virtue of the heat generated by the currents induced in it. May it not be that, anti-effective influence, such as is thus produced by copper not forming part of the circuit, can be produced by copper actually in the circuit if the conductor be too thick? Examining the question mathematically, I find that it must be answered in the affirmative, and that great augmentation of the effective ohmic resistance is actually produced if the conductor be too thick; especially in coils consisting of several layers of wire laid over one another in series around a cylindric or flat core (as in various forms of transformers).

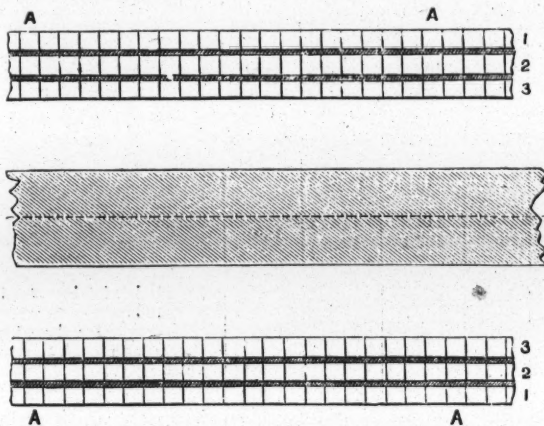


FIG. 1.

2. Fig. 1 may be imagined to represent the secondary coil of a transformer consisting of solid square copper wire in three layers. For simplicity, we suppose the axial length to be infinitely great, and straight; but the uniformity which this involves, and a close practical application to its simplicity is realised in that excellent form of transformer which consists of a toroidal iron core completely covered by primary and secondary wires laid on toroidal surfaces. To simplify the mathematical work, I suppose the whole thickness of the three layers to be small in comparison with the greatest radius of curvature of the circular or flat cylindric surface on which the wire is wound, but if it is not so the solution is easily obtained, for the case of circular cylinders, in terms of the Fourier-Bessel functions. It is of no consequence for our present question what there be inside of coil No. 3, and if we please we may imagine there to be nothing but air; the drawing, however, indicates an iron core and space which might be occupied by the primary coil, if a transformer is the subject; or our coil, A, A, A, A, may be the primary coil of a transformer with secondary coil and core inside it, and the alternate current maintained in it by an external electromotive agent acting in an arc between its ends outside. Our present results are applicable to all these varieties of cases indifferently, all that is essential being that the total quantity of current be given at each instant, and be uniform throughout the whole length of the coiled conductor.

3. This last condition is secured by perfectness of insulation between all contiguous turns of the coil, unless we were considering so enormously long a coil that the quantity of electricity required for the essential changes of static electrification would be sensible as constituting drafts from, or contributions to, the current in the coil. The consideration of static electrification involved in the maintenance of alternate currents through a coil such as that represented in fig. 1, is exceedingly curious and interesting; but we do not enter on it at present at all, as in all practical cases the quantities concerned are quite infinitesimal in comparison with the whole quantity flowing in one direction or the other in the half period.

4. In the drawing, the section of the wires is represented as square, but this is not essential, and in practice a flat rectangular

ribbon would, no doubt, for some dimensions of coils, be preferable. I assume the thickness of the insulation between the successive squares or rectangles in each layer to be infinitely small in comparison with the breadth of the rectangle; but the thickness of the insulation between successive layers, which is a matter of indifference to my calculations, may be anything, and would in practice naturally be, as shown in the diagram, considerably greater than the thickness of the insulation between the contiguous portions of the coil in each layer.

5. The full mathematical work which I hope to communicate to the *Philosophical Magazine* for publication in an early number, includes an investigation of the self-induction of the coil, with or without anything in its interior (such as core, or primary wire of a transformer), but, at present, I merely give results so far as effective ohmic resistance, or generation of heat in the interior of the wire of the coil, A, A, A, A, itself is concerned; which, as said above, is independent of everything in the interior, and of the mode in which the alternating current is produced, provided only that the total amount of electricity crossing the section of the wire per unit of time be given at each instant.

6. As a preliminary to facilitate the expression of these results, it is convenient first to give a general statement of the solution of the problem of laminar diffusion of a simple harmonic variation, applied to the case of electric currents in a homogeneous conductor. Let the periodically varying magnetic force in the air or other insulating material in the neighbourhood of so small a portion, s , of the surface of a conductor that we may regard it as plane be given. Resolve this magnetic force into two components, one perpendicular to s which we may neglect, as it has no influence in connection with the currents we are to consider; the other parallel to s , which we shall call the effective component, and denote by γ . Through any point, o , of s , draw three rectangular lines, ox , oy , oz , of which oy and oz are in s , and ox is parallel to the direction of the effective magnetic force component, γ . Let now the value of γ at time, t , be

$$\gamma = M \cos \frac{2\pi t}{T},$$

where M denotes a constant, and T the period of the alternation. The varying magnetic force, z , to whatever cause it may be due, gives rise to currents parallel to ox in the conductor, expressed by the following formula for γ , the current intensity at distance, x , from the plane, s , provided x be small enough to fulfil the condition stated below:—

$$\gamma = \frac{M}{\lambda \sqrt{2}} e^{-\frac{2\pi x}{\lambda}} \cos \left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \frac{1}{4}\pi \right),$$

where λ denotes what we may call the wave length of the disturbance and is given in the terms of T , the period of the disturbance, and ρ and ω the resistivity and magnetic permeability of the substance, by the following formula:—

$$\lambda = \sqrt{\frac{T\rho}{\omega}}.$$

For copper we have $\omega = 1$, and $\rho = 1611$ square centimetres per second; and thus for 80 periods per second $\lambda = 4.49$ or, say, $4\frac{1}{2}$ centimetres.

In order that the formula for γ may be approximately true, it is necessary, in the first place, that λ must be small in comparison with the distance we must travel in any direction in the surface of s , before finding any deviation of it from the tangent plane through o , comparable with λ . Secondly, for a very good approximation, λ must be so small that we may be able to travel inwards, in any direction from o , through a space equal to at least twice λ , without coming to any other part of the bounding surface of the conductor. If, for example, the surface be a flat plate, this condition requires that the thickness be more than twice λ . But (because $e^{-\pi}$ is less than $1/23$), the formula gives a very fair approximation, requiring for a half the thickness of the plate inwards from s no greater correction than about 4 per cent, even if the thickness of our plate be no greater than λ . When the thickness of the plate is less than 2λ , we may consider waves of electric current as travelling inwards from its two sides and being both sensible at the middle of the plate; and a complete solution of the problem is readily found by the method of images. But, a direct analytical investigation, by which the proper conditions of relation to varying magnetic force on the two sides of the plate are fulfilled is the most convenient way of fully solving the problem, and it is thus that the results given below have been obtained.

7. The smallness of the insulating space between the successive turns in each layer of our coil A, A, A, A, and the equality of the whole current through them all, prevent any surface disturbance from being produced at the contiguous faces, and allow the problem to be treated as if, instead of a row of squares or rectangles we had a continuous plate forming each stratum. The smallness of the thickness of this plate in comparison with the radius of the cylindric surface to which it is bent, allows, as said above, the mathematical treatment for an infinite plate bounded by two parallel planes to be used without practical error. I have thus found an expression for the intensity of the current at any point in the metal of any one of the layers of a coil of one, two, three, or more layers; and have deduced from it an expression for the quantity of heat generated per unit of time, at any instant, per unit breadth in any one of the layers. I need not at present quote the former expression; the latter is as follows. With q to denote

the dynamical value in time average of the heat generated, per unit of time at different instants of the period, per unit breadth and unit length in layer No. i from the outside of the coil, c^2 the time average of the square of the total current per unit breadth, and a the thickness of the layer

$$q = \frac{2\pi\rho}{\lambda} \rho \Theta c^2$$

$$\text{where } \Theta = \frac{\epsilon^{2\theta} + 2 \sin 2\theta - \epsilon^{-2\theta}}{\epsilon^{2\theta} - 2 \cos 2\theta + \epsilon^{-2\theta}} + 2i(i-1) \frac{\epsilon^\theta - 2 \sin \theta - \epsilon^{-\theta}}{\epsilon^\theta + 2 \cos \theta + \epsilon^{-\theta}}$$

$$\text{and } \theta = \frac{2\pi a}{\lambda}$$

8. The numerical results shown in the table have been calculated, and the accompanying graphic representation (fig. 2), drawn, for me by Mr. Magnus Maclean.

TABLE OF VALUES OF θ .

$\frac{16\theta}{\pi}$	$i = 1$	$i = 2$	$i = 3$	$i = 4$
1	5.113	5.118	5.127	5.141
2	2.553	2.592	2.669	2.786
4	1.316	1.634	2.270	3.224
6	.9854	1.997	4.019	7.053
8	.9173	2.993	7.143	13.37
10	.9452	4.062	10.30	19.65
12	.9822	4.899	12.73	24.48
14	1.000	5.276	13.83	26.66
16	1.002	5.362	14.08	27.16
∞	—	5.00	13.00	25.00

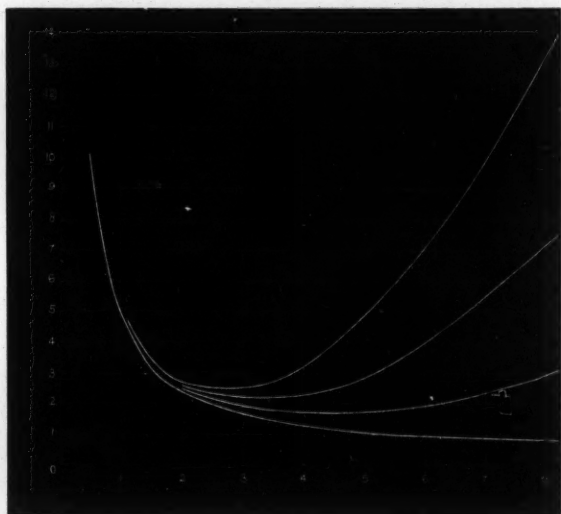


FIG. 2.

8. We see from the table and curves that each curve has a minimum distance from the line of abscissas, and that each comes to a horizontal asymptote, parallel to the line of abscissas, for $\theta = \infty$. By looking at the formula, we see that there is, in fact, an infinite succession of minimums and maximums in the expression for Θ , but it is only the first minimum, and the following maximum, that occur within the range of variation of θ , which we regard as sensible. In the case of $i = 1$, the formula gives $\theta = \frac{1}{2}\pi$ for the first minimum. The curves show for the

case of $i = 2, 3, 4$, respectively, the first minimum at $\frac{16\theta}{\pi} = 4\frac{1}{2}, 3$, and $2\frac{6}{10}$, respectively. The thickness which corresponds to $\theta = \pi$ is the half wave length of the electric disturbance, which, as we have seen is for copper 2.244 centimetres, when the frequency of the alternations is 80 periods per second; and for this case, therefore, the thicknesses that give minimum generation of heat in the first, second, third, and fourth layers are, respectively, 11.22, 6.31, 4.21, and 3.65 millimetres. Anything more of continuous copper than these thicknesses in any of the layers would be not merely ineffective or comparatively ineffective, but would be positively anti-effective. Even with so small a thickness as 2.8 millimetres, for copper and frequency 80, line 2 of the table (corresponding to a sixteenth of the wave-length) shows, in the first, second, third, and fourth layers, losses of 0.3 per cent., 2 per cent., 5 per cent., and 10 per cent. in excess of that due to the true ohmic resistance of the copper, were it all effective. When the size chosen for the transformer and the amount of output required of it are such that a thickness of $2\frac{1}{2}$ millimetres in the direction perpendicular to the

layers is insufficient, a remedy is to be had by using braided wire, or twisted strand, with slight insulation of varnish or whitewash, crushed or rolled into rectangular or square form of the desired thickness and breadth. A very slight resistance between the different wires thus crushed together would suffice to cause the current to run nearly enough full bore to do away with any sensible loss from the cause which forms the subject of this communication.

ON THE FORM OF SUBMARINE CABLES FOR LONG DISTANCE TELEPHONY.

By W. H. PREECE, F.R.S.

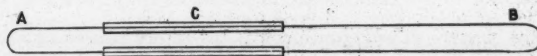
(Read before Section G, September 9th, 1890.)

At the Newcastle meeting last year, I gave the reasons and experiments which led to the conclusion that telephoning between London and Paris was practical. New and distinct aerial lines of four copper wires are now being erected by the respective governments from each capital to the coast, and a new cable, the joint property of the two governments, will be laid during this year, between the Kent coast and Sangatte, to connect these two lines. There will thus be two metallic circuits between the two capitals. The κR , that is the product of the capacity, κ , and the resistance, R , of each circuit, upon which the clearness of articulation depends, will be 5,900, indicating that speech should be excellent.

A somewhat similar circuit has been established, since October last, between Buenos Ayres and Monte Video, under my advice. The cables across the La Plata are each 28 miles long, for there are two separate single wire cables, and the total distance between the two cities is 180 miles. Subscribers, who have metallic circuits in each city, have no difficulty whatever in speaking to each other from their respective offices, although the κR is as high as 10,400.

The cable across the Channel will be a four-wire cable, and the specification for its construction has been based on the following mathematical development by Mr. H. R. Kempe.

Let there be a looped telephonic line between A and B, with a cable C, at an intermediate point on the route.



The working capacity of the whole line is dependent upon the product of the total resistance, R , and the total capacity κ . Therefore, if we take the resistance of the aerial portion of the line to be a fixed quantity, there will be a particular size of cable conductor which will give the smallest possible size of dielectric, sufficient to enable a particular value of κR not to be exceeded. For, if we make the conductor larger than this size, and thereby diminish its resistance, we can, it is true, do with an increased capacity, but the diminution in the thickness of the dielectric which could thereby be allowed, is more than compensated for by the fact that the surface of the conductor is larger; in other words, we increase the capacity in a greater proportion than we diminish the resistance. If, on the other hand, we diminish the size of the conductor, we increase the resistance in a greater proportion than we diminish the capacity. Strictly speaking, the requirements of the problem are to determine the size of cable core which shall cost least; but inasmuch as the costs of gutta-percha and copper, bulk for bulk, do not differ greatly, the problem resolves itself into the determination of the smallest outer diameter which can be employed.

Let

$$\begin{aligned} r &= \text{total resistance of aerial line,} \\ \rho &= \text{,, ,, cable,} \\ k &= \text{,, capacity of aerial line,} \\ \kappa &= \text{,, ,, cable.} \end{aligned}$$

Then

$$\kappa R = (k + \kappa)(r + \rho).$$

Let

$$\begin{aligned} D &= \text{diameter of dielectric of cable,} \\ x &= \text{,, ,, conductor ,,} \end{aligned}$$

Then

$$\rho = \frac{a}{x^2} \text{ and } \kappa = \frac{b}{\log_{\epsilon} \frac{D}{x}}$$

where a and b are constants.

We have, therefore,

$$\kappa R = \left(k + \frac{b}{\log_{\epsilon} \frac{D}{x}}\right) \left(r + \frac{a}{x^2}\right)$$

therefore

$$\frac{b}{\log_{\epsilon} \frac{D}{x}} = \frac{\kappa R}{r + \frac{a}{x^2}} - k = \frac{\kappa R - k \left(r + \frac{a}{x^2}\right)}{r + \frac{a}{x^2}}$$

therefore

$$\log_{\epsilon} \frac{D}{x} = \frac{b \left(r + \frac{a}{x^2}\right)}{\kappa R - k \left(r + \frac{a}{x^2}\right)}$$

therefore

$$\log_e D = \frac{b \left(r + \frac{a}{x^2} \right)}{\kappa R - k \left(r + \frac{a}{x^2} \right)} + \log_e x$$

$$= \frac{r + \frac{a}{x^2}}{\frac{\kappa R - k r}{b} - \frac{k a}{b x^2}} + \log_e x = \frac{r + \frac{1}{x^2}}{\frac{\kappa R - k r}{a b} - \frac{k}{b x^2}} + \log_e x$$

$$= \frac{A + \frac{1}{x^2}}{B - \frac{C}{x^2}} + \log_e x = u, \text{ say}$$

where

$$A = \frac{r}{a}$$

$$B = \frac{\kappa R - k r}{a b}$$

$$C = \frac{k}{b}$$

Now to make D a minimum we must make $\log_e D$ (that is u) a minimum, and this we have to do by variation of x , therefore we have

$$\frac{d u}{d x} = \frac{1}{\left(B - \frac{C}{x^2} \right)^2} \left\{ \left(B - \frac{C}{x^2} \right) \frac{2}{x^3} - \left(A + \frac{1}{x^2} \right) \frac{2 C}{x^3} \right\} + \frac{1}{x} = 0$$

therefore

$$\frac{1}{x} = \frac{1}{\left(B - \frac{C}{x^2} \right)^2} \left\{ \left(B - \frac{C}{x^2} \right) \frac{2}{x^3} + \left(A + \frac{1}{x^2} \right) \frac{2 C}{x^3} \right\}$$

$$= \frac{2}{x^3 \left(B - \frac{C}{x^2} \right)^2} \left\{ \left(B - \frac{C}{x^2} \right) + \left(A + \frac{1}{x^2} \right) C \right\}$$

$$= \frac{2}{x^3 \left(B - \frac{C}{x^2} \right)^2} \{ B + A C \}$$

therefore

$$x^2 \left(B - \frac{C}{x^2} \right)^2 = 2 \{ B + A C \}$$

therefore

$$x \left(B - \frac{C}{x^2} \right) = \sqrt{2 \{ B + A C \}}$$

therefore

$$B x - \frac{C}{x} = \sqrt{2 \{ B + A C \}}$$

therefore

$$x^2 - x \frac{\sqrt{2 \{ B + A C \}}}{B} = \frac{C}{B}$$

From which, by solving the quadratic equation, we get

$$x = \frac{\sqrt{B + A C} + \sqrt{B + A C + 2 B C}}{\sqrt{2 B}}$$

Now, careful experiments made on an aerial line of copper wire, weighing 200 lbs. per mile (diameter = 112 mils.), the wire being 30 feet above the ground showed that the inductive capacity per mile was .015 microfarads very nearly, consequently the capacity per mile is expressed by the formula

$$\frac{.061637}{6.1583625 - \log d}$$

d being the diameter of the wire in mils.

From this formula the capacity per mile of a wire weighing 400 lbs. works out .0156 m.f. The average resistance per mile of a wire of this weight is 2.25 ohms.

Taking the distance between London and Dover to be 70 miles, and between Calais and Paris to be 180 miles, the total distance of the loop will be 500 miles, which for a 400 lbs. copper wire gives the resistance

$$r = 500 \times 2.25 = 1,125 \text{ ohms.}$$

Now, in the case of a looped wire, the total capacity equals half that of a single wire, hence

$$k = \frac{.0156 \times 250}{2} = 1.95.$$

Assuming the length of the cable to be 21 knots, we have approximately

$$\rho = \frac{42 \times 74,402}{x^2} \text{ for copper of 98 per cent. conductivity at } 60^\circ \text{ F.}$$

so that

$$a = 3,124,884.$$

The ordinary standard core used by the Post Office has a con-

ductor diameter of 86.41 mils., and a gutta-percha diameter of 285 mils., and a capacity of 1/3 m.f. per knot, and as

$$\text{capacity per knot} = \frac{\text{const.}}{\log \frac{D}{d}}$$

we have

$$\frac{1}{3} = \frac{\text{const.}}{\log \frac{285}{82.087}}$$

or

$$\text{const.} = \frac{\log \frac{285}{82.087}}{3} = .18018997$$

The capacity of 42 knots of looped cable will be half that of 21 knots of single cable, hence

$$\kappa = \frac{.18018997 \times \frac{21}{2}}{\log \frac{D}{x}} = \frac{1.8919947}{\log \frac{D}{x}}$$

$$= \frac{4.356481}{\log_e \frac{D}{x}}$$

so that

$$b = 4.356481$$

We have then for 400 lbs. wire

$$a = 3,124,884$$

$$b = 4.356481$$

$$r = 1,125$$

$$k = 1.95$$

If we take $\kappa R = 7,500$, which is the highest value that can safely be taken, we get

$$B = \frac{7,500 - 1.95 \times 1,125}{3,124,884 \times 4.356481} = .000389779$$

$$2 B C = \frac{2 \times .000389779 \times 1.95}{4.356481} = .000348937$$

$$\sqrt{2 B} = .000551231$$

$$A C = \frac{1.95 \times 1,125}{3,124,884 \times 4.356481} = .0001611454$$

From this we get

$$\sqrt{B + A C} = .02347177$$

$$\sqrt{B + A C + 2 B C} = .0299977$$

$$\sqrt{2 B} = .000551231$$

$$\text{so that } x = \frac{.02347177 + .0299977}{.000551231} = 97.00014$$

$$\text{and extreme diameter of strand} = 97.00014 \times \frac{100}{95} = 102.1054 \text{ mils.}$$

Since $\kappa R = (k + \kappa) (r + \rho)$

we get

$$\kappa = \frac{\kappa R}{r + \rho} - k$$

$$= \frac{7,500}{1.125 + \frac{3,124,884}{(97.00014)^2}} - 1.95 = 3.197153$$

But

$$\kappa = \frac{1.89199468}{\log \frac{D}{x}}$$

therefore

$$\log D = \frac{1.89199468}{\kappa} + \log x = \frac{1.89199468}{3.197153} + 1.9867724$$

$$= 2.5785475 = \log \text{ of } 378.86$$

$$= 380 \text{ mils approximately.}$$

If we take

$$x = 95 \quad \text{then } D = 378.94$$

$$,, \quad 97.00014 \quad ,, \quad 378.86$$

$$,, \quad 99 \quad ,, \quad 379.08$$

which proves the correctness of the calculation for a minimum.

The values of these diameters correspond very closely to a core, the weight of whose conductor is 160 lbs., and the weight of whose gutta-percha covering is 300 lbs., and it has therefore been decided to adopt those dimensions.

Although the calculation has been made on the assumption that the land lines on both sides of the cable are to be of 400 lbs. wire, the French Government have decided that the wires to be erected by them shall be of 600 lbs. weight; the result of this will be to reduce the value of κR to 5,900, as stated at the commencement of the paper.

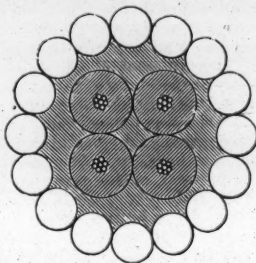
The specification of the cable states that:—(1) Each conductor shall be formed of a strand of seven copper wires all of equal diameter, shall weigh 160 lbs. per nautical mile, and shall at a temperature of 75° Fahrenheit have a resistance not higher than 7.632 ohms or lower than 7.478 ohms per nautical mile.

(2) Each conductor shall be insulated by being covered with

three alternate layers of Chatterton's compound and gutta-percha, beginning with a layer of the said compound, and no more compound shall be used than may be necessary to secure adhesion between the conductor and the layers of gutta-percha. The dielectric on each conductor shall weigh 300 lbs. per nautical mile, making the total weight of each conductor when covered with the dielectric 460 lbs. per nautical mile.

(3) The inductive capacity of such insulated conductor shall not exceed .3045 microfarad per nautical mile.

(4) The insulation resistance of each coil of core shall be not less than 500 megohms per nautical mile after such coil shall have been kept in water maintained at a temperature of 75° Fahrenheit for not less than 24 consecutive hours immediately preceding the test, and after electrification during one minute.



The cores (four in number) are to be served with the best wet fully tanned yarn, and with a sheathing of 16—280 mil. wires, each having a minimum breaking strain of 3,500 lbs., and a minimum of 10 twists in 6 inches. The section of the cable is shown by the fig.

SUGGESTIONS TOWARDS A DETERMINATION OF THE OHM.

By Prof. J. V. JONES, Principal and Professor of Physics in the University College of South Wales and Monmouthshire, Cardiff.

(Read in conjunction with the Discussion on Electrical Units, in Section A, September 5th, 1890.)

"ON the whole I am of opinion that if it is desirable at the present time to construct apparatus on the most favourable scale so as to reach the highest attainable accuracy, the modification of Lorenz's method, last described, is the one that offers the best prospect of success. Before this is done, however, it appears to me important that the value now three times obtained in the Cavendish Laboratory, by distinct methods, should be approximately verified (or disproved) by other physicists. To distinguish between this value and those obtained for instance by Kohlrausch, by Lorenz, or by the first B. A. Committee, should not require the construction of unusually costly apparatus. Until the larger question is disposed of, it seems premature to discuss the details of arrangements from which the highest degree of precision is to be expected."

The above passage which concludes a paper communicated by Lord Rayleigh to the *Philosophical Magazine*, in November, 1882, nearly two years before the Electrical Congress at Paris, at which the legal ohm was defined to be the resistance of a column of mercury of 1 sq. mm. section and 1,060 mm. long, seems not to have met with adequate response in this country. So far as published experiments in English laboratories are concerned, the determination of the ohm remains where Lord Rayleigh left it, except for the contribution made by Glazebrook and Fitzpatrick in their measurement of the specific resistance of mercury in terms of the B.A. unit, which is one of the elements in the determination of the specific resistance of mercury in absolute measure by Lord Rayleigh's adaptation of Lorenz's method.

But though in England the scientific world has during the last seven or eight years occupied itself with other things, in other countries, and more especially in America and France, measurements have been made which have confirmed the Cavendish Laboratory result as against the other values mentioned by Lord Rayleigh in the passage quoted. Further, indication has already been given of the intention to employ as the unit of electrical resistance in the new Government Standardising Laboratory not the so-called legal ohm but the true ohm as nearly as it can be determined, and Major Cardew in the paper recently read by him before the Institution of Electrical Engineers has invoked the assistance of Lord Rayleigh and the British Association Electrical Standards Committee in the preparation of the required unit. The work judged necessary by Lord Rayleigh before the conditions of a more accurate determination could be advantageously discussed having been done; and practical necessity for an authoritative determination having arisen in connection with the standardising laboratory, the time seems ripe for a consideration of arrangements likely to secure high accuracy, and it is with this view that I venture to bring before the section the suggestions embodied in this paper.

In the hope of paving the way for a more accurate determination (and initially moved to the work by the invitation given in the passage which I first read) I have for a considerable time been engaged in submitting to the test of experiment certain modifications of the method of Lorenz which occurred to me as likely to lead to increased accuracy and certainty. I do not propose to

trouble the section with the details of these experiments, which I hope may be published elsewhere. I mention them merely to give the suggestions brought forward the support derived from a determination actually made on the lines indicated. The experiments have been made in the laboratory of the University College at Cardiff with apparatus for the most part constructed in the college workshop. Five complete sets of observations were taken in the spring of this year with the following results for the specific resistance of mercury at 0° C. :—

(i.)	94,103	absolute units
(ii.)	94,074	" "
(iii.)	94,093	" "
(iv.)	94,045	" "
(v.)	94,021	" "

Mean 94,067 ± 10 (probable error). The result may be otherwise expressed by saying that the ohm is equal to the resistance of a column of mercury of 1 square mm. sectional area, and 106.907 centimetres long, the probable error being ± 0.012.

It is far from my intention to bring these numbers forward as the best determination possible by the method I have used. I do not think they at all represent the accuracy attainable if the apparatus were to be constructed on a scale a little larger, and with a certain perfecting of detail. Under such circumstances I am of opinion that a single set of observations will give a result accurate to one part in ten thousand, and that as a mean of a number of observations we may, perhaps, aim at the hundred-thousandth if regard is paid to the maintenance of definite temperatures in all parts of the apparatus, and if we can be said to know our length standards to this degree of accuracy.

In Lorenz's method a metallic disc is made to rotate in the mean plane of a coaxial standard coil. Wires touching the centre and circumference of the disc are led to the ends of the resistance to be measured, and the same current is passed through this resistance and the standard coil. The connections being rightly made we may, by varying either the rate of rotation of the disc or the resistance to be measured, so arrange matters as to have no change of current in the circuit of the disc and wires joining it to the ends of the resistance when the direction of the current through the resistance and the standard coil is changed. When this arrangement is effected there is a balance between the electromotive force due to the motion of the disc in the magnetic field of the current in the standard coil, and the difference of potential at the ends of the resistance due to the current traversing it. If this adjustment is made, let us say that the apparatus is in an equilibrium position.

If M = the coefficient of mutual induction of the standard coil and the circumference of the disc;

n = the rate of rotation of the disc (number of revolutions per second);

R = the resistance;

γ = the current through the standard coil and resistance;

then, in an equilibrium position,

$$M n \gamma = R \gamma$$

or

$$M n = R.$$

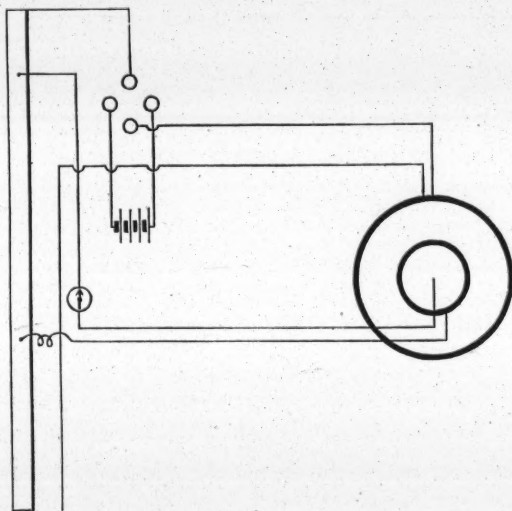
In practice it is not possible to take the coefficient of mutual induction and the rate of rotation large enough to make the measured resistance more than a small fraction of an ohm*; and this has usually been regarded as one of the difficulties of Lorenz's method.

In order that the absolute unit may be recoverable at pleasure without the fatigues of a new absolute determination, it must be defined in practice by reference to the specific resistance of some standard substance, and for many reasons there is a consensus of opinion in making this standard substance mercury. The determination of the ohm as a practical problem, therefore, becomes identical with the determination of the specific resistance of mercury in absolute measure, and the small resistance measured by the method of Lorenz's must, in order to complete the investigation, be brought into relation and compared with the specific resistance of mercury. Lorenz himself evaded the difficulty by taking for his measured resistance the resistance of a mercury column contained in a glass tube; the resistance of the column was then obtained in absolute measure, and the specific resistance calculated from the dimensions of the column. It is hardly possible, however, that the latter calculation can have been, or is likely to be, achieved with accuracy, however accurately the tube be calibrated. For, on the one hand, if the wires from the disc (the terminal portions of which may be called the electrodes) are led to the ends of the tube, the equipotential surfaces touched by them are not plane; and, on the other, if they are let into the tube at some distance from the ends, it is difficult to see how the distance between them is to be measured with the requisite accuracy.

Under these circumstances Lord Rayleigh preferred to use solid conductors, overcoming the difficulty of comparing the resistance measured with ordinary standards by a shunt method, which made it possible to express it at once in terms of the B.A. unit. The B.A. unit being thus found in absolute measure, a separate investigation of the specific resistance of mercury in terms of the B.A. unit completed the determination. Rowland and others have adopted the shunt method of Lord Rayleigh, which may be said to be an essential feature in the more probable determinations

* Lorenz .0008 002.
Rayleigh .002 004

by Lorenz's method. Spite of the conspicuous success which has attended the use of solid conductors by the shunt method, I venture to suggest a reversion to Lorenz's use of mercury. The physical constant to be measured is the specific resistance of mercury, and if this can, by direct measurement, be determined with accuracy, it seems inconvenient and undesirable first to determine the resistance of the B.A. unit in absolute measure, and then to determine the specific resistance of mercury in B.A. units. If consistently with accuracy the artificial B.A. unit can be dropped out of our experiments as well as out of the result; and the measurements made directly on mercury, the simplicity would seem to be a recommendation, and the argument is perhaps enforced by the consideration that there is very nearly as much divergence in the results of different observers for the specific resistance of mercury in B.A. units as there is in the values obtained for the B.A. unit in absolute measure.



The objections to the use of mercury in a tube are unanswerable; but the difficulties disappear if instead of placing the mercury in a tube, it is placed in a long trough, and if instead of measuring the distance between the two electrodes, one electrode is kept fixed while measurement is made of the distance moved through by the other between two equilibrium positions corresponding to two different rates of rotation of the disc. The latter measurement it is easy to make with accuracy, for the movable electrode may be rigidly attached to the movable headstock of a Whitworth measuring machine or some other measuring bank placed parallel to the length of the trough; and the two equilibrium positions may be taken near the middle of the trough so as to avoid danger of curvature in the equipotential surfaces passing through the electrode in its two positions.

Let n_1, n_2 be the rates of rotation of the disc, and let l be the distance between the corresponding equilibrium positions of the movable electrode.

Then

$$M(n_1 - n_2) = \frac{l}{A} \rho$$

where ρ = the specific resistance of mercury.
 A = area of section of the mercury column.

But we are met by a new difficulty, the determination of the section of the mercury column. The capillary depression at the sides of the trough would make it a most serious task to determine the section by direct measurement to the required degree of accuracy.

Fortunately, this difficulty may be overcome by a further differential method, viz., by making observations with the mercury at two different heights in the trough.

Let b = the breadth of the trough;
 $h_2 - h_1$ = the difference of height of the mercury surface in the two cases;
and let A = the section of the mercury column when the mercury is at the lower position.

Then we have, denoting by dashed letters, the new values of the rates of rotation and the distance between the corresponding equilibrium positions—

$$M(n_1 - n_2) = \frac{l}{A} \rho$$

and

$$M(n'_1 - n'_2) = \frac{l'}{A + b(h_2 - h_1)} \rho$$

whence eliminating A

$$\rho = \frac{M b (h_2 - h_1)}{l' - \frac{l}{n'_1 - n'_2} - \frac{l}{n_1 - n_2}}$$

It is assumed in the above formula that the sides of the trough in that part of it traversed by the movable electrode are plane, parallel, and vertical.

Hence the determination of the specific resistance involves the determination of:—

- (i.) Four equilibrium positions, two at each depth, with the rates of rotation of the disc to which they correspond.
- (ii.) The breadth of the trough in that part of it traversed by the movable electrode.
- (iii.) The difference of level of the mercury surface at the two depths.
- (iv.) The coefficient of mutual induction of the coil and disc.

The difficulties attached to the determination of equilibrium positions and the coefficient of mutual induction belong to all forms of Lorenz's method, whether the resistance measured is that of a solid conductor or that of a mercury column. Those specially incident to the use of a mercury column are:—

- (i.) The manufacture of an accurate trough, and
- (ii.) The accurate measurement of the difference of level of the mercury surface in its two positions.

The trough used by me in the experiments of which I have spoken, was cut in paraffin wax contained in a strong casting of iron with its sides strengthened by outside ribs. The channel is approximately 43.5 inches long, by 1.5 inches broad, by 3 inches deep. It was first cut by a cutter rotating about 2,000 times a minute, attached to the slide rest of the College Whitworth Lathe, and subsequently finished by a scraper, attached in similar fashion, which took a very thin cut off sides and bottom. The result of the scraping was a very smooth and highly finished surface.

This method of obtaining a channel for the mercury was adopted in the hope that so cut in the lathe it might present a breadth constant to two or three ten thousandths of an inch. This hope was not realised: the results of subsequently calibrating the trough over the 10 inches of it traversed by the movable electrode indicated a variation of as much as .001 inch in its breadth. The objections to the use of paraffin wax are:—

- (i.) Its softness makes it necessary to proceed with great care in measuring its breadth, lest damage should be done to the surface. This difficulty is satisfactorily surmounted in the form of internal callipers adopted in the calibration, which I must not stay to describe.

- (ii.) The coefficient of expansion of paraffin wax is very large, its linear coefficient of expansion being about .0003. A change of temperature would, therefore, cause distortion in the wax channel seeing that the wax is enclosed in an iron casing.

We endeavoured to meet the danger of inaccuracy due to this cause by measuring the breadth of the trough as nearly as possible at the same temperature as that at which the electrical observations were made, care being taken to maintain the trough at a uniform temperature throughout the observations. During the month of the observations, the temperature inside the box in which the trough was placed, did not vary more than half a degree. But, notwithstanding this care, I am of opinion that the difference in the result of different sets of observations depends in the main upon variations in the trough due to varying temperature. But it is impossible to apply a correction, for paraffin wax is so bad a conductor of heat that its temperature could not be assumed to be that of the thermometers in the mercury channel; its temperature at any part would really be a function of ancient history.

Under these circumstances, I have come to the conclusion that I made a mistake in my choice of a substance; the disadvantages outweigh the apparent ease of construction. Probably a much more satisfactory result would be obtained by building up the trough of worked glass or scraped marble. I do not doubt that a sufficiently accurate trough might be made in either of these substances without straining the resources of the English mechanical engineer. We may observe that small errors become of less importance as the breadth of the trough is increased; and nothing but practical convenience limits the size of the trough we may employ, provided it is long enough in proportion to its breadth to make the equipotential surfaces plane over the part of it traversed by the movable electrode. It is further to be noticed that it is only the latter part of it that needs to be finished with the highest accuracy, and when the mechanical engineer has done his best, it is still possible to obtain a further approximation by a process of calibration.

The position of the mercury surface in the trough may be determined electrically by means of a pointed steel spherometer screw. The screw may be moved downwards until an electric circuit, comprising the screw and the mercury, is completed. It is of the utmost importance that the point of the screw should be kept clean, and that the mercury surface should be free from an oxide film, otherwise successive observations may differ from one another as much as .001 inch; but with clean mercury, if the point is carefully wiped with filter paper before making the observations, half a dozen observations may be without difficulty obtained, none of which differ from the mean by more than .00004 inch. To preserve the point, sparking at the mercury surface should be reduced as much as possible.

In order that the capillary surface should be of the same shape at both levels, the surface should always be brought to its measured position by pouring mercury into the trough, and never by taking mercury out of it.

I am of opinion that both the measurements to which I have referred as peculiar to the direct use of mercury by the differential method—viz., that of the breadth of the trough and that of the difference of level of the mercury surface—may be made with an

accuracy which will compare favourably with that which we can hope for in the determination of the equilibrium position; and, perhaps, also with that which we may expect in the measurement of the coefficient of mutual induction—measurements which are common to all forms of Lorenz's method.

Probably, also—though here I speak with hesitation and without experience—the accuracy will be as great as, if not greater than, that which attends the calibration of a glass tube, necessary to the determination of the specific resistance of mercury in B.A. units.

The electrical observations in Lorenz's method consist, fundamentally, in the determination of equilibrium positions, together with the rates of rotation to which they correspond. The equilibrium position is obtained when, if the direction of the current is reversed through the standard coil and trough, the reading of a galvanometer inserted in the disc circuit is unaffected. In the experiments I have made, I have found it best—following Lord Rayleigh—to take two sets of galvanometer readings for each equilibrium position, one set giving the change of galvanometer reading corresponding to reversal of the battery current for a position of the electrode slightly to one side of the equilibrium position; the other, the change of galvanometer reading, corresponding to reversal for a second position slightly on the other side of the equilibrium position. The galvanometer reading corresponding to the two positions of the commutator being called x and w , passage through an equilibrium position is indicated by a change in the algebraic sign of $w - x$. When $w - x$ has been found for two positions slightly differing from one another, and including between them the equilibrium position, the latter may be found by simple interpolation. Since the readings, x and w , are not quite fixed, owing to small changes in the speed of the disc and variations at the brush contacts, it is necessary to take a number of reversals and to find $w - x$ as the mean of the values obtained by combining the first value of x with the first of w , the first of w with the second of x , the second of x with the second of w , &c. The more quickly the reversals can be made to succeed one another, the better will be the results, for with rapid reversal variations in the position of the needle corresponding to no current through the standard coil (i.e., variations due to change at the brush contacts), are less likely to supervene. It is, therefore, best not to wait for the needle to come even approximately to rest after the disturbance due to the induction current on reversal, but to take the readings for the extreme positions in an oscillation, and having previously found the coefficient of damping, to calculate the position of rest from these two readings.

The whole difficulty in determining an equilibrium position arises from the want of constancy in the readings x and w ; and this want of constancy is due to two causes:—

1. Variations in the electromotive force at the brush contacts.
2. Variations in the rate of rotation of the disc.

It was with a feeling akin to despair that I watched the dance of the galvanometer needle during the first running of my apparatus, when the brush at the circumference of the disc was composed of a number of layers of thin phosphor bronze sheet controlled by a spring, and the dance continued, however well the circumference of the disc and brush were amalgamated at starting. Trials were made in the hope of improvement with amalgamated copper and amalgamated lead, and with the substitution of a dead weight pressure for the spring. But no satisfactory result could be obtained. It was noticed, however, that after amalgamation the readings were fairly steady for a short interval, and it occurred to me that if mercury could be continuously supplied to the surface of contact between the brush and the disc, this steadiness might be maintained. This led on to the idea of a brush consisting of a single wire perforated by a channel through which a constant flow of mercury might be maintained from a cistern of adjustable height; and a brush of this description was finally adopted. It presents very great advantages over any other form of brush tried.

Prof. Rowland used three brushes on the circumference instead of one, and I do not doubt that a multiplication of brushes is advantageous. Three or more such brushes as I have described, resting by dead weight pressure on the circumference of a disc ground true in place would, I believe, give an excellent result. The grinding of the disc in place is an important aid to steadiness of galvanometer reading.

It is to be noticed that the value of $w - x$ for a position at a given distance from the equilibrium position is proportional to the current through the standard coil. Hence the small variations due to the brush contacts which do not at all depend on the current through the coil become proportionately of less importance as the current is increased. We ought, therefore, from this point of view, to use as large a current as possible. But the magnitude of the current is limited by the fact that it has to traverse the wire of the standard coil, which must not be made so hot as to risk the destruction of its insulation. This consideration points to the use of wire of considerable diameter in the standard coil.

If the wire of the coil is made of large diameter, attention must be paid to the influence on the coefficient of mutual induction of the non-coincidence of the current with the axis of the wire.

The second cause of want of steadiness in the galvanometer needle is variation in the rate of rotation of the disc; and this is the real crux. We are not helped in determining the equilibrium position either by increasing the sensitiveness of the galvanometer or the magnitude of the current through the coil, unless we procure a corresponding increase of steadiness in the running of the disc. We may increase the value of $w - x$ for a position at a given distance from an equilibrium position in either of these ways,

but unless there is a corresponding improvement in the constancy of the disc rotation no advantage results, for the variations in w and x resulting from changes of speed are proportional to $w - x$. Hence in the construction of apparatus for a new determination mechanical engineers should be invited to do their very best to procure a constant rotation. No time or trouble spent in securing this will be lost for the purpose in view.

In my experiments the disc was turned by an electromotor directly coupled to it, and driven from a battery of secondary cells. Each bearing was fitted with sight feed lubricators, and a heavy steel flywheel was attached to the motor. The current passed to the motor through resistance coils, and could be varied continuously through a small range by a slide resistance of platinum wire, after the larger adjustment had been made to obtain a speed, approximately that which was required. A shunt worked by a lever also provided the means of taking out or putting in a small resistance suddenly, so as to allow the observer taking note of the speed to counteract small variations, due to alteration in the lubrication of the bearings.

To obtain improved steadiness, the chief point needing attention is lubrication. Some forced system of lubrication may be employed. Either oil may be pumped through the bearings, or they may be fed from a cistern placed at some height above them. Attention might also be directed to the friction of the brushes on the motor commutator. I do not think we can look hopefully to an increase of steadiness from the employment of any hand brake controlled by the observer, for the mischief is done, and the alteration has come about before he observes that it is his duty to put the brake on or off. In fact, the galvanometer needle picks up the alterations much sooner than the observer's eye. An electro-magnetic brake might be useful for adjusting the speed, but could not give any additional steadiness to the galvanometer needle. This can, I think, only be procured by perfection of mechanical workmanship, and increased attention to the truth of all rubbing surfaces, and their proper lubrication.

It remains to speak of the measurements necessary to enable the calculation of the coefficient of mutual induction to be performed. To facilitate an accurate determination of the mean radius of the standard coil, I desire to suggest that it should be a coil consisting of one layer of wire. The advantage in constructing a standard coil with a single layer of wire is that every part of it is visible, and that nothing is done to alter the position of the wire after measurements are made. If a coil consists of many layers, it is not quite easy to say where, after measurement, the lower layers go to under the pressure of the superincumbent layers. Lord Rayleigh found, in the case of certain coils used by him, that the mean radius calculated from measurements made in winding was greater by one part in 2,000 than the mean radius calculated from measurements made in unwinding, a result clearly due to the compression of the lower layers by the layers above them.

We should, therefore, expect that if the mean radius of a coil of many layers is calculated from measurements made in winding, it will be reckoned too large. In the face of this, it is interesting to note that in the measurements made by Lord Rayleigh by the method of Lorenz, the series in which the coils are so placed as to make the induction coefficient nearly independent of the mean radius, gives a result rather larger than the other series, which is what might be expected, if the mean radius is over-estimated. But the smallness of the variation (a little over one part in 10,000), seems to show that the error of mean radius must be very small for the pair of coils used by Lord Rayleigh. In general, we should expect as far as this cause goes, that values of the specific resistance in determining which coils of many layers are used would come out too low, since an overestimate of the mean radius of the coil means an underestimate of the coefficient of mutual induction. The apparent disadvantage of a coil of a single layer is that the number of turns will be fewer and, therefore, the coefficient of mutual induction of the coil and disc smaller than in the case of a coil of many layers. We may, however, in order to get a sufficient number of turns, make the coil of greater axial length than has been customary. But we cannot, in that case, use Lord Rayleigh's formula of approximation in calculating the coefficient of mutual induction. Under these circumstances, a new formula, applicable to a coil of moderate axial length, was a desideratum. Such a formula I obtained by

the direct integration of the expression $\iint \frac{ds ds'}{r} \cos \epsilon$ for a circle and coaxial helix.

It is of the form

$$M = -8\pi n \frac{Aa}{A+a} \sum (-1)^m \frac{1.3.5 \dots 2m-1}{2.4.6 \dots 2m} \cdot \frac{1}{2m+1} \left(\frac{a}{A+a}\right)^{2m} P_m.$$

Where A = the radius of a circular section of the cylinder determined by the helix.

a = the radius of the circle.

n = the number of turns of the helix.

$2x$ = the axial length of the helix.*

and

$$P_m = \int_0^\pi \frac{\cos 2\theta d\theta}{(1 - c^2 \sin^2 \theta)^{\frac{2m+1}{2}}}$$

* *Phil. Mag.*, January, 1889. Read before Physical Society, November 10th, 1888.

when

$$c = \frac{2\sqrt{Aa}}{A+a}$$

r_m may be expressed in terms of c , r (c), and π (c).

This is the formula I have used in calculating the coefficient of mutual induction of the coil and disc in the experiments already mentioned. The coil is of double silk covered copper wire of about .02 inch diameter, resting in a screw thread of .025 inch pitch, cut on a hollow cylinder of brass of about 21 inches external diameter. The axial length of the cylinder is something over 4.5 inches, and 185 turns of wire are wound on it. The disc has a radius of about 6.5 inches, and the coefficient of mutual induction is about 17,000 inches. This is a little more than a tenth of the coefficient of mutual induction of the coils and disc used by Lord Rayleigh in the first and second series of his experiments by the method of Lorenz, but it was found to be ample for the purpose in hand.

The mean radius of the coil was measured in the Whitworth measuring machine.

Uncertainty arose from two causes:—

- (i.) The silk covering of the wire;
- (ii.) The ellipticity of the coil cylinder.

The silk covering of the wire is of slightly varying thickness, and suffers compression to a varying extent during a series of measurements.

A standard coil, consisting of naked wire wound in a screw thread cut on a cylinder of insulating material, would be preferable to one of covered wire wound on a metal cylinder. There is, however, difficulty in finding a suitable insulating material. Wood immediately occurs to one's mind, but a large coil of wood, even though it be built up many pieces, is apt to change its shape with age and varying atmospheric conditions. But if a suitable insulating material, that can be turned true and that will retain its shape can be found, a single layer of naked wire in a screw thread cut on a cylinder of this material, would give us a coil the mean radius of which might be easily measured with certainty in the Whitworth machine to far more than one part in ten thousand.

The ellipticity of the coil cylinder deserves notice. The cylinder was turned with great care in the lathe already mentioned. It was cast with three lugs by which to bolt it to the face plate, and subsequently in precisely similar fashion to the strong brass frame which serves as its support during use. The first operation was roughly to fit the lugs to the face plate by filing. A roughing cut was then taken over the entire surface of the cylinder, so as to get rid of as much as possible of the internal strain due to unequal cooling of the casting. It was next unbolted and the lugs were carefully scraped to fit the face plate, and after again bolting it to the face plate the final turning was proceeded with. Very fine cuts were taken in finishing, and it was hoped that by these precautions we should secure a true right circular cylinder. Nevertheless measurements made in the Whitworth measuring machine show that the section of the cylinder at right angles to its axis is slightly oval. The longest diameter is 21.1056, and the shortest 21.0898, from which it appears that there is a difference of about .008 inch between the longest and shortest radius. It appears, indeed, to be a task of no ordinary difficulty to turn a cylinder of large size that shall remain true to the thousandth of an inch. Every fresh cut seems to alter its internal equilibrium, and after the cut is complete it adjusts itself to a new shape. The remedy lies in having a sufficiently massive cylinder carefully annealed to work on, and a fund of patience to make the requisite number of fine finishing cuts with a sufficient interval of time between them. In conclusion, the main suggestions I have to offer for consideration are the following:—

(I.) That the time is ripe for a new determination of the ohm that shall be final for the practical purposes of the electrical engineer.

(II.) That such a determination may be made by the method of Lorenz, the specific resistance of mercury being obtained directly in absolute measure by the differential method described.

(III.) That the standard coil should consist of a single layer of wire, the coefficient of mutual induction of the coil and disc circumference being calculated by the new formula.

DISCUSSION.

Mr. SWINBURNE having suggested certain alterations in the moving parts of Prof. Jones's apparatus,

Lord RAYLEIGH said that he was very much interested in the paper. When he first planned observations by the method of Lorenz, he naturally cast about to see whether he could imitate him and deal as Prof. Jones had done with an actual column of mercury. He found certain difficulties which at the time choked him off, and which Prof. Jones had overcome. He was quite conscious that good results might be obtained in that way, and it was of great interest to obtain them in that way. This was a distinct variation from the methods used by others. Here they had mercury brought directly into the absolute measurement. He was not quite sure whether he rightly understood Prof. Jones as to the manner in which connection with the mercury column was made. He thought as far as he did understand him, the movable electrode of which he spoke, was the one which actually carried the main current.

Prof. JONES said the current through the standard coil was introduced to the mercury by thick iron plates at the end of the open trough.

Lord RAYLEIGH thought that that arrangement commended

itself to them. What he attempted was as follows:—He took a closed tube of about 1 inch in diameter, and in order to get lateral connections he divided it, cutting it as clean as he could at two places into three parts, and then filing away a little bit of the edge, put them together with cement, leaving in that way the cavities through which the lateral wires could be introduced. He thought the amount of disturbance of the regular sections induced in that way was not much; and he was sure if it were gone into in a careful manner, good results would be obtained. Prof. Jones had used an open trough with a free surface in order to eliminate the effect of meniscus, by a differential arrangement of which the depth was varied. His only remark as to that would be that, as Prof. Jones explained it, it seemed to require four observations to get a result. That rather accumulated errors of reading, though not to a serious extent probably. He had very little doubt that by this method extremely accurate results might be got; and, no doubt, if Prof. Jones pursued the subject, he might obtain a degree of accuracy surpassing any yet obtained. He was not sure whether so high a degree of accuracy was very important at the present moment. No doubt they would like to get a greater degree of accuracy than they had obtained; but he was not sure that there were any other measurements with which that could be brought into comparison. Supposing they could, how could they use the number unless in comparison with other numbers obtained in other physical measurements? Nothing definite would follow from it, and if they used it for electrical purposes they had to face the difficulty of comparing wire with mercury. The only other point was as to the question of the temperature of the mercury. When a comparatively thin tube filled with mercury was used, there was no difficulty in immersing it in ice. Was the mercury in Prof. Jones's apparatus at zero?

Prof. JONES: No. 15.5°.

Lord RAYLEIGH: Then it depends upon the change in mercury.

Prof. JONES: Yes. The speaker went on to say that he used the formulae of Mascart and Benoit.

Lord RAYLEIGH said that that correction could be made with a great degree of accuracy, but it took away from the method that consisted in the comparison. However, there could be no doubt of the very great interest of getting that result direct in terms of mercury without the inconvenience of any other standard, and he hoped Prof. Jones would pursue it.

Sir WILLIAM THOMSON mentioned one point as a source of error, viz., meniscus. Prof. Jones said that the meniscus was taken as the result of adding to the mercury in each case. If it was so finely balanced as that, he would be afraid that even tapping it during experiments would alter the level of the surface and induce error. No doubt Prof. Jones attended to that, but it was necessary to make quite sure that the error from meniscus did not sensibly vitiate the result, and if it did, by how much? As to temperature, he should think that its determination might be got with great accuracy by thermometers placed in the mercury itself at considerable distances in the parts subject to the differential test; two or three points at some distance from where the mercury was tapped would do. He was glad that Lord Rayleigh advised Prof. Jones to pursue the method which seemed, so far, exceedingly satisfactory.

Lord RAYLEIGH said he meant to have expressed his appreciation of the advantage of being able to reduce a coil to a single layer. No one who had measured a coil would doubt that. There was a question of the uniformity of the winding in the other direction—whether the windings were uniform along the axis? Prof. Jones said that they were laid on a screw throughout.

Prof. JONES briefly replied on the remarks made.

ON ALTERNATE CURRENTS IN PARALLEL CONDUCTORS OF HOMOGENEOUS OR HETEROGENEOUS SUBSTANCE.

By Sir WM. THOMSON.

(Read before Section A, September 5th, 1890.)

This paper consists of a description of some of the results of a full mathematical investigation of the subject which I hope to communicate to the *Philosophical Magazine* for an early number.

1. Two or more straight parallel conductors, supposed, for simplicity, to be infinitely long, have alternating currents maintained in them by an alternate current dynamo, or other electromotive agent applied to one set of their ends at so great a distance from the portion investigated, that in it the currents are not sensibly deviated from parallel straight lines. The other set of ends may, indifferently in respect to our present problem, be either all connected together without resistance, or through resistances, or through electromotive agents. All that we are concerned with at present is, that the conductors we consider form closed circuits, or one closed circuit; and that, therefore, the total quantities of electricity per unit of time at any instant traversing the normal sections in opposite directions are equal.

2. We suppose the period of the alternation to be very great in comparison with the time taken by light to traverse a distance equal to the greatest diameter of cross-section of our whole group of conductors. This supposition is implied in the previous assumptions of parallel rectilinearity of the electric stream-lines, and of equality of the quantities of electricity traversing, in opposite directions, the several areas of a normal section.

3. We farther suppose that the length of our conductors and

their effective ohmic resistances, are so moderate,* that the quantities of electricity deposited on, and removed from, their boundaries to supply the electrostatic forces along the conductors required for producing the alternations of the currents, are negligible in comparison with the total quantity flowing in either direction in the half-period. This supposition excludes important practical problems of telegraphy and telephony, the problem of long submarine cables for instance, but it includes the problem of electric lighting by alternating currents transmitted at high tension through considerable distances, as, for example, from Deptford to London.

4. The general investigation includes as readily any number of separate circuits of parallel conductors, as a single circuit, but for simplicity in describing results, I suppose our system of conductors to be so joined at their ends as to constitute a single simple circuit of two parallel conductors.† It may be either two conductors or one conductor, one of which may or may not surround the other, as shown in figs. 1 and 2, representing cross sections. Each conductor may be single, as in figs. 1 and 2; or either may be multiple parallels.

5. We suppose each conductor to be homogeneous in substance and in cross section from end to end, but not necessarily homogeneous in different parts of the cross section. Thus the different

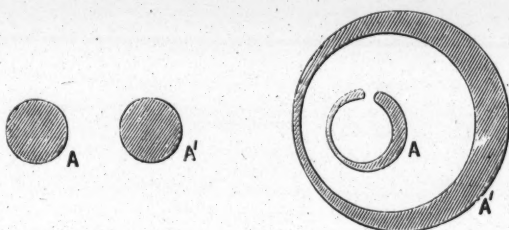


Fig. 1

Fig. 2.

conductors, or the different parts of either, may be of different metals, or either conductor, or any part of either conductor, may consist of two metals (as iron and copper or iron and lead) laid parallel and soldered together.

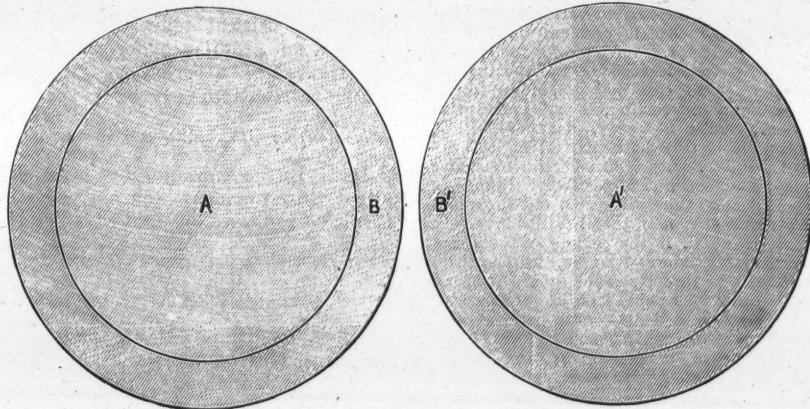


Fig. 3.

6. We shall call A and A' the cross sectional areas, or groups of areas of the two conductors, respectively, of the other. All the different portions of A are connected metallically at their two ends, and are thus all of them at one potential at one end and

* The circumstances in which this condition is fulfilled may be usefully illustrated by considering the important practical cases of submarine cables, and of metallic circuits of two parallel wires insulated at a distance anything less than a few hundred times their diameter. For all these cases the numeric expressing the electrostatic capacity per unit length of either conductor (the other supposed for the moment to be at zero potential) is between 2 and 0.1, and for our present rough comparison may be regarded as moderate in comparison with unity. On this supposition the condition of the test requires for fulfilment that the mean proportional between the velocity which expresses in electro-magnetic measure the resistance of one of the conductors, and the velocity of a body travelling the length of the conductor in a time equal to half the period of alternation shall be exceedingly small in comparison with the velocity of light.

† The case of a single circuit made up of parallel conductors, so joined at their ends that to travel once round it we must go and come two or three or more times along separate conductors, joined by their ends in series, so as to make one circuit, is specially considered in my paper on "Anti-Effective Copper in Parallel or in Coiled Conductors for Alternating Currents," to be communicated presently to Section A.

another potential at the other end, and similarly for A' . The homogeneity of the material and of the cross sections along the length of the conductors, and the uniformity of the total currents assumed in Section 3, implies that all the different parts of A in one cross sectional plane are at one potential, even though A consist of mutually isolated parts, or A' consist of mere isolated parts. If, as in figs. 1 and 2, all the parts of A are in mutual metallic connection, and all the parts of A' are in mutual metallic connection, this would entail uniformity of potential through A , and uniformity of potential through A' , even without the limitation of our subject laid down in Section 3.

7. The following are among some of the most noteworthy results of the full mathematical treatment of the subject:—

I. When the period of alternation is large in comparison with 400 times the square of the greatest thickness or diameter of any of the conductors, multiplied by its magnetic permeability, and divided by its electric resistivity, the current intensity is distributed through each conductor inversely as the electric resistivity; the phase of alternation of the current is the same as the phase of the electromotive force; and the current across every infinitesimal area of the cross-section is calculated, according to the electromotive force at each instant, by simple application of Ohm's law.

II. When the period is very small in comparison with 400 times the square of the smallest thickness or diameter of any of the conductors, multiplied by its magnetic permeability, and divided by its electric resistivity, the current is confined to an exceedingly thin surface stratum of the conductors. The thickness of this stratum is directly as the square root of the quotient of resistivity, divided by magnetic permeability of the substance in different parts of the surface, but the total quantity of the current per unit breadth of the surface is independent of the material, and, except in such cases as those referred to at the end of II. below, varies in each cross section in simple proportion to the electric surface density of the static electrification induced by the electromotive force applied between the extremities for maintaining the current. The distribution of this electric density is similar in all cross sections, but its absolute magnitude at corresponding points of the cross section varies along the length of the conductor in simple proportion to the difference of electric potentials between A and A' , and is zero at one end in the particular case in which the conductors are connected through zero resistance at one end while the electromotive force is applied by an alternate current dynamo at the other end. On the other hand, the surface-distribution of

electric current is uniform throughout the whole length of the conductors, and it is only its distribution in different parts of the cross-section that varies as the electric density.

The proportionality of surface intensity of the current to electric density, asserted above, fails clearly in any case in which the circumstances are such that the distance we must travel along the surface to find a sensible difference in electric density is not very great in comparison with the thickness of the current-stratum. Such a case is represented in fig. 3, which is drawn to scale, for alternate currents of period $\frac{1}{100}$ th of a second in round rods of copper of 6 cms. diameter. The spaces between the outer circular boundaries and the inner fine circles, indicate what I have called the mhoic thickness,* being $\cdot 714$ of a centimetre for copper of resistivity 1611 square centimetres per second. The full solution for such a case as that represented in fig. 3, belongs to the large class of cases intermediate between I. and II., and could only be arrived at by a kind of transcendent mathematics not hitherto worked. But without working it out, it is easy to see how the time-maximum intensity of the current will diminish inwards from the surface, and will be, at any point of either of the inner fine circles, about $\frac{1}{2}$ or $\frac{1}{3}$ of what it is at the nearest point of the boundary surface: and that at points in the surface, distant from B or B' by one-half or one or two times the mhoic thickness, the current intensity will be much smaller than it is at B or B' .

III. In case I. the heat generated per unit of time, per unit of

* Collected Papers, Vol. III., Art. CII., § 35.

volume, in different parts of the conductors, is inversely as the electric resistivity of the substance, and directly as the square of the total strength of current at any instant. In case II. the time-average of the heat generated per unit of time, per unit of area of the current stratum, is as the time-average of the square of the quantity of current per unit breadth, multiplied by the square root of the product of the electric resistivity into the magnetic permeability.

IV. Example of II.—Let the conductor, A, be a thin flat bar, as shown in the diagram (fig. 4), A' being a tube surrounding A, or another flat bar like A, or a conductor of any form whatever, provided only that its shortest distance from A is a considerable multiple of the breadth of A. The thickness of A must be sufficiently great to satisfy the condition of II., and its breadth must be a large multiple of its thickness. (For copper carrying alternating currents of frequency 80 periods per second, these conditions will be practically fulfilled by a flat bar of 4 cms. thickness, and 30 or 40 cms. breadth). The current in it is chiefly confined to two strata extending to small distances inwards from its two sides. (For copper and frequency 80 periods per second, the time maximum of intensity of the current at the surface will be about e^2 , or 7.4, times what it is at a distance 1.43 cms. in from the surface. The quantity of current per unit breadth, or as we may for brevity call it, the surface-density of the current in each stratum, is determined by the well-known solution of the problem of finding the surface electric density of an electrified ellipsoid of conductive material undisturbed by any other electrified body. The case we have to consider is that of an ellipsoid whose longest diameter is infinite, medium diameter the breadth of our flat conductor, and least diameter infinitely small. In this case the electric density varies inversely as $\sqrt{(a^2 - x^2)}$. The graphic construction in the drawing shows $r \cdot q = \sqrt{(a^2 - x^2)}$, and we conclude that the time-

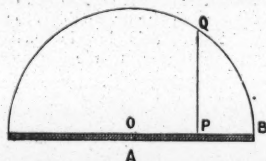


Fig. 4.

maximum of the surface density of the current varies inversely as $r \cdot q$. The infinity which in the electric problem we find for electric density of the ideal conductor, is obviated for the electric current problem by the proper consideration of the rectangular corners, or the rounded edge (as the case may be), of our copper bar, which, though exceedingly interesting, is not included in the present communication. Suffice it to say, that there will be no infinities even if the corners be true mathematical angles.

V. Examples of cases I. and II. —Let A consist of three circular wires, c, l and i, of copper, lead, and iron respectively. In case I., the quantities of the whole current they will carry, and the quantities of heat generated per unit of time in them, will be inversely as their resistivities. In case II., if the centres of the three circular cross-sections form an equilateral triangle, the quantities of heat generated in them will be directly as the square roots of the resistivities for c and l; and for i would be as the square root of the product of the resistivity into the magnetic permeability, if the magnetic permeability were constant and the viscous or frictional resistance to change of magnetism nothing for the iron in the actual circumstances. This last supposition is probably true, approximately, with a permeability of $\frac{1}{25}$ th for iron or steel, according to Lord Rayleigh, if the current is so small that the greatest magnetising force acting on the iron is less than 0.1 C.G.S.

VI. The dependence of the total quantity carried, on extent of surface, and on the solution of the electrostatic problem described in II, justifies Snow Harris, and proves that those who condemned him out of Ohm's law were wrong, in respect to his advising tubes or broad plates for lightning conductors, but does not justify him in bringing them down in the interior of a ship (even through the powder magazine), instead of across the deck and down its sides, or from the masts along the rigging and down the sides to the water. The non-dependence of the total quantities of current on the material, whether iron or non-magnetic metals, seems quite in accordance with Dr. Oliver Lodge's experiments and doctrines regarding "Alternative Path" and lightning conductors. The case of alternate currents is, of course, not exactly that of lightning discharges; but from it, by Fourier's methods, we infer main conclusions of II. and V., whether the discharges be oscillatory or non-oscillatory, provided only that it be as sudden as we have reason to believe lightning discharges are.

DISCUSSION.

Prof. ROWLAND said that he had considered these alternating currents in parallel conductors, and he believed he gave a theorem with regard to the distribution in the case of perfect conductors. He thought that that was the only case in which the problem could be solved. In that case the distribution was exactly the same as it would have been if they had been charged with electricity at rest; and there was some theorem, which he had almost

forgotten now, with regard to the self-induction and the capacity. In that special case the self-inducting capacity. Of course, that was a much more limited problem than that Sir William Thomson had given, but he thought it led to interesting results. It guided them in their ideas with regard to the distribution, because in the case of perfect conductors the distribution of the current was exactly the same as the distribution of the density in the case of conductors at rest, so making the conductivity a little less than that; and they were guided to some extent by that theorem. He did not know that any solution had ever been obtained in the case where the conductors were not perfect, but Sir William Thomson, he considered, had found a solution of that nature.

CORRESPONDENCE.

Hysteresis.

I have not much to say about this subject, which is occupying many of our minds, but I must kindly be allowed to call the attention of those of your readers who are interested in the subject to a short but remarkable paper by Prof. Ewing in the *Philosophical Magazine* for this month; it is simply charming.

The manner of expression, and total absence of mathematical gas and turnpike roads, which is so often apparent in such work, is not only to the advantage of many who want the crop, but who cannot, for different reasons, follow the plough and harrow; but in other respects it is so highly suggestive, and so face-to-face in its experimental truth, that its effect upon intelligent readers must be more than ordinary; it is more than probable that from it they will learn more of magnetism than from their past digestion of tons of theories. I am glad Prof. Ewing has mentioned his line and fields of magnetic needles, and expandable base of rubber to shift their centres, the development of magnetic swing into "rotation," the lag explanation, and critical temperatures; but I will not go further, but promise everyone one of the finest scientific treats from a perusal of Prof. Ewing's latest magnetic contribution.

James C. Richardson.

September 9th, 1890.

P.S.—In the same number is an elaborate account all about glow-worms, which may also interest many who think we get too few light rays from our lamps.

Electric Launches.

Much is often said of the advantages of electric launches, and comparisons are drawn between them and steam launches, to the great disadvantage of the latter. I have no particular partiality to the steam launch, and think it often a great nuisance to boating men on the Thames, but I am not aware that a great drawback to the use of some electric launches has been noted, namely, the smell. This, if present, has not been noticed by me in connection with the larger launches, but there is a small launch which may often be seen not 15 miles from London, which is a great sinner in this respect. In pulling down stream a few days ago, with the wind blowing towards me, I recognised the presence of this boat some hundreds of yards before reaching her, and remarked upon it to a friend who was steering; he said he could see nothing of her; but shortly after, we passed her towing a boat almost as large as herself. This nuisance is, of course, from the acid in the cells. I do not know what type is in use, but such a boat is a bad advertisement for the electric launch business.

E. R. Dolby.

September 9th, 1890.

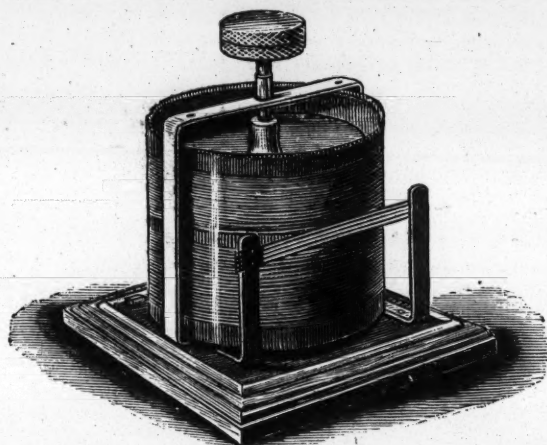
The Electric Light in Portsmouth.—The *Portsmouth Times* regards this as inevitable, and says that vested interests, referring to the Portsea Island Gas Company, must not be allowed to stop the way.

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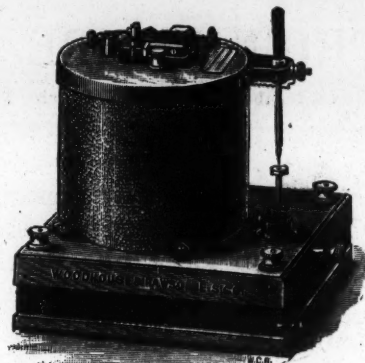
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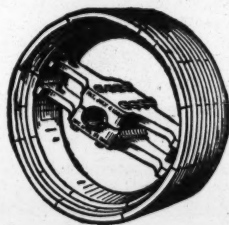
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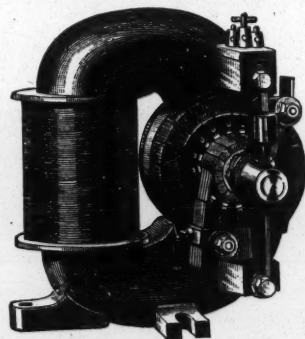
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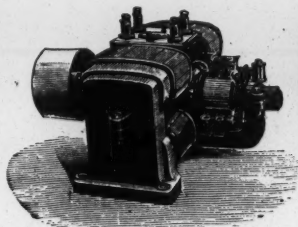
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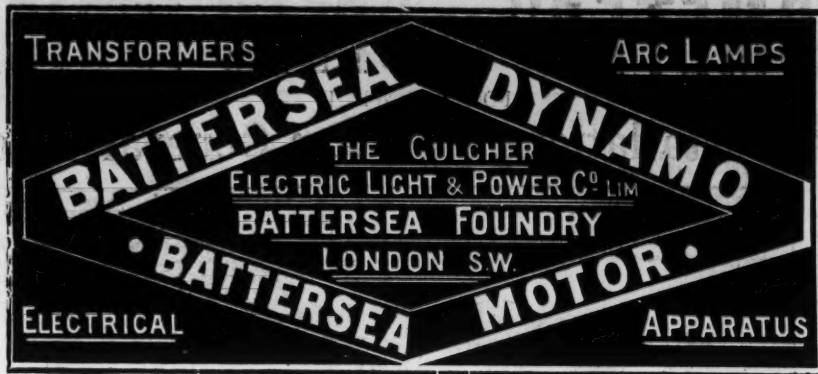
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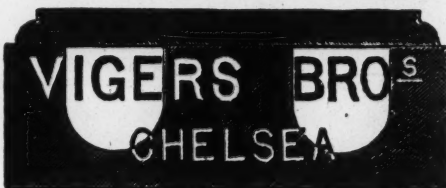
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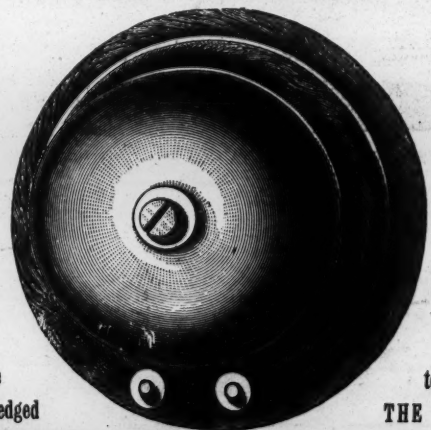
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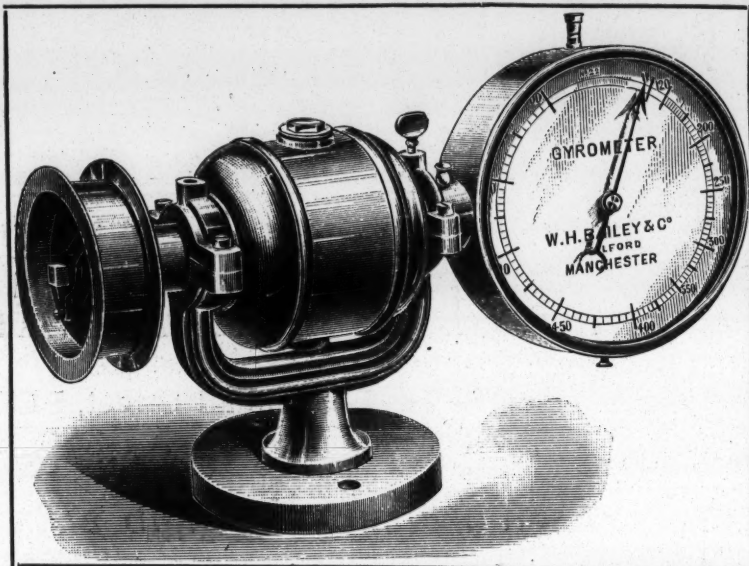
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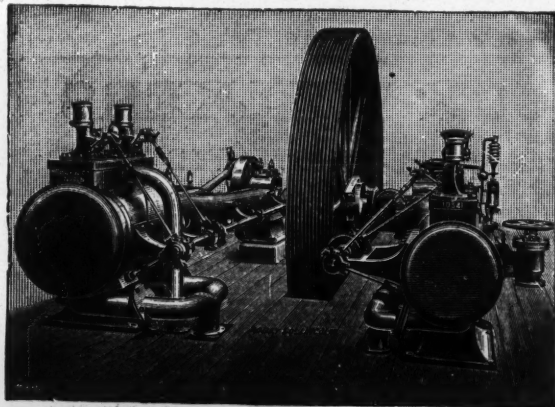
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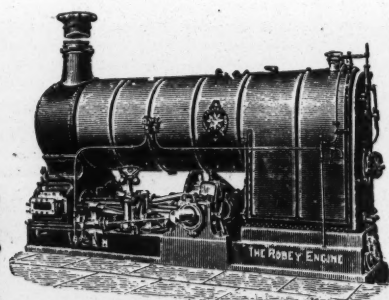
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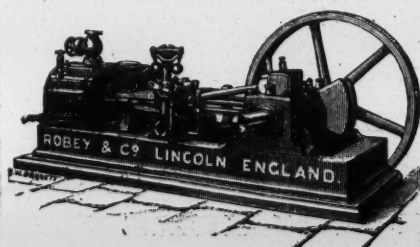
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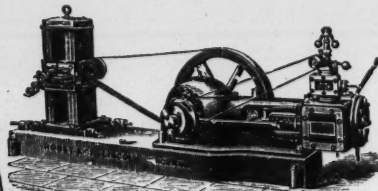
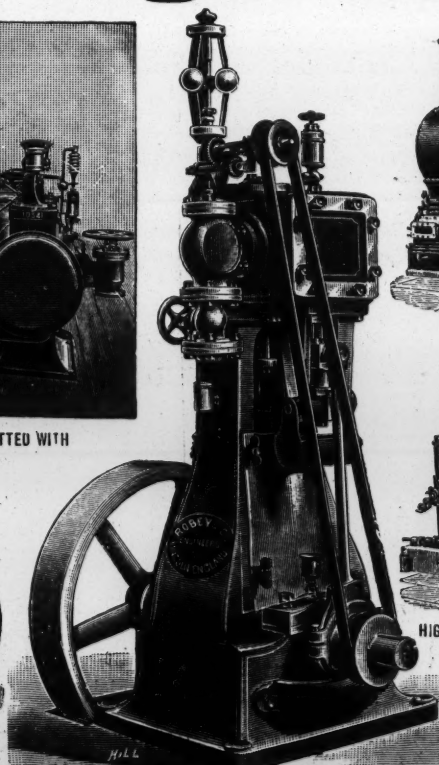
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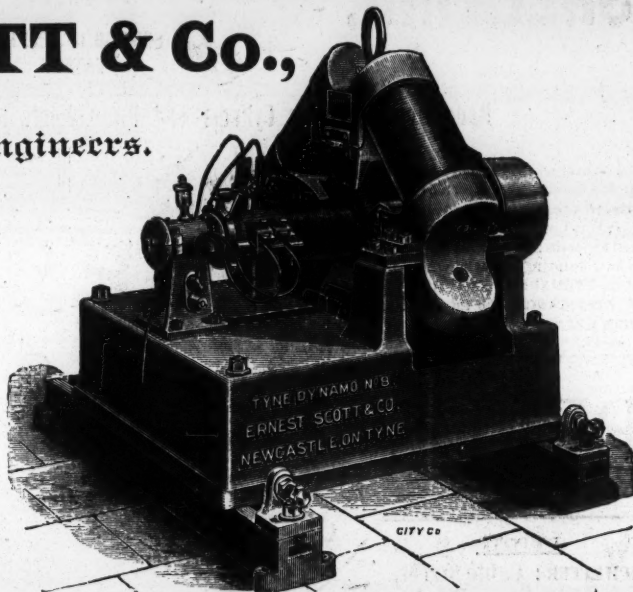
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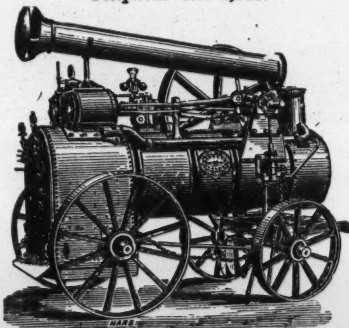
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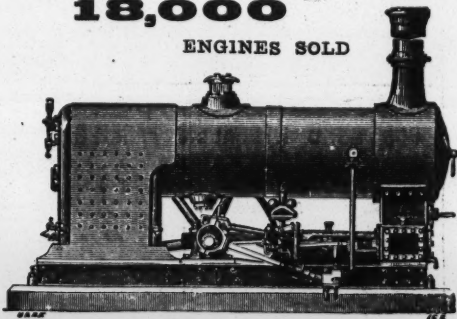
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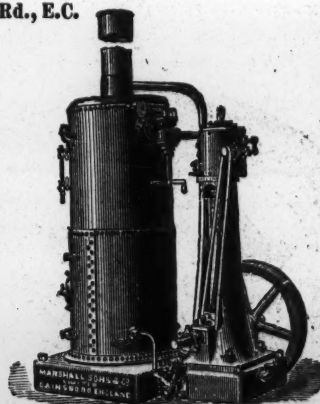
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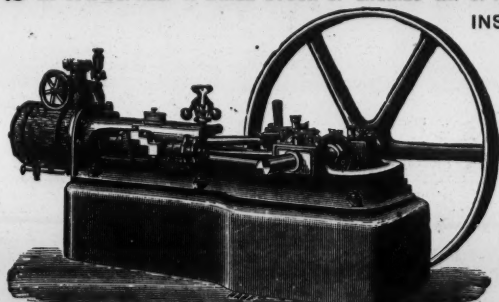


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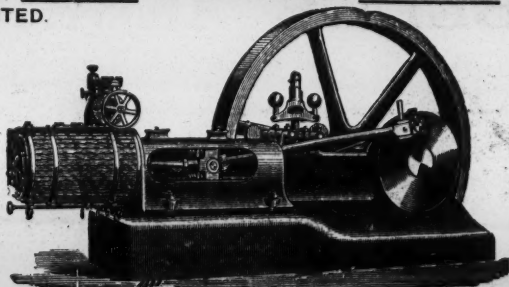
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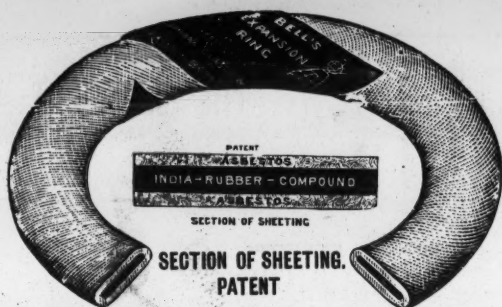
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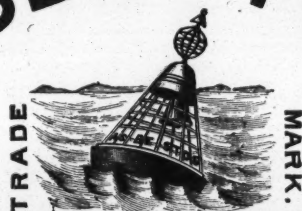
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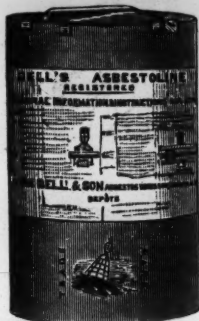
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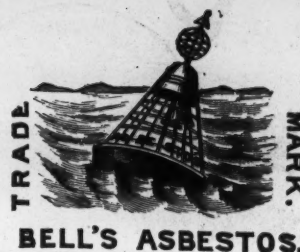
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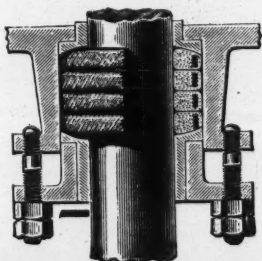
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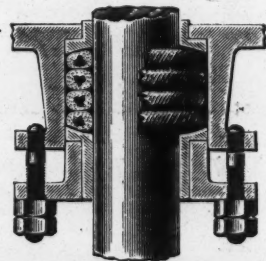
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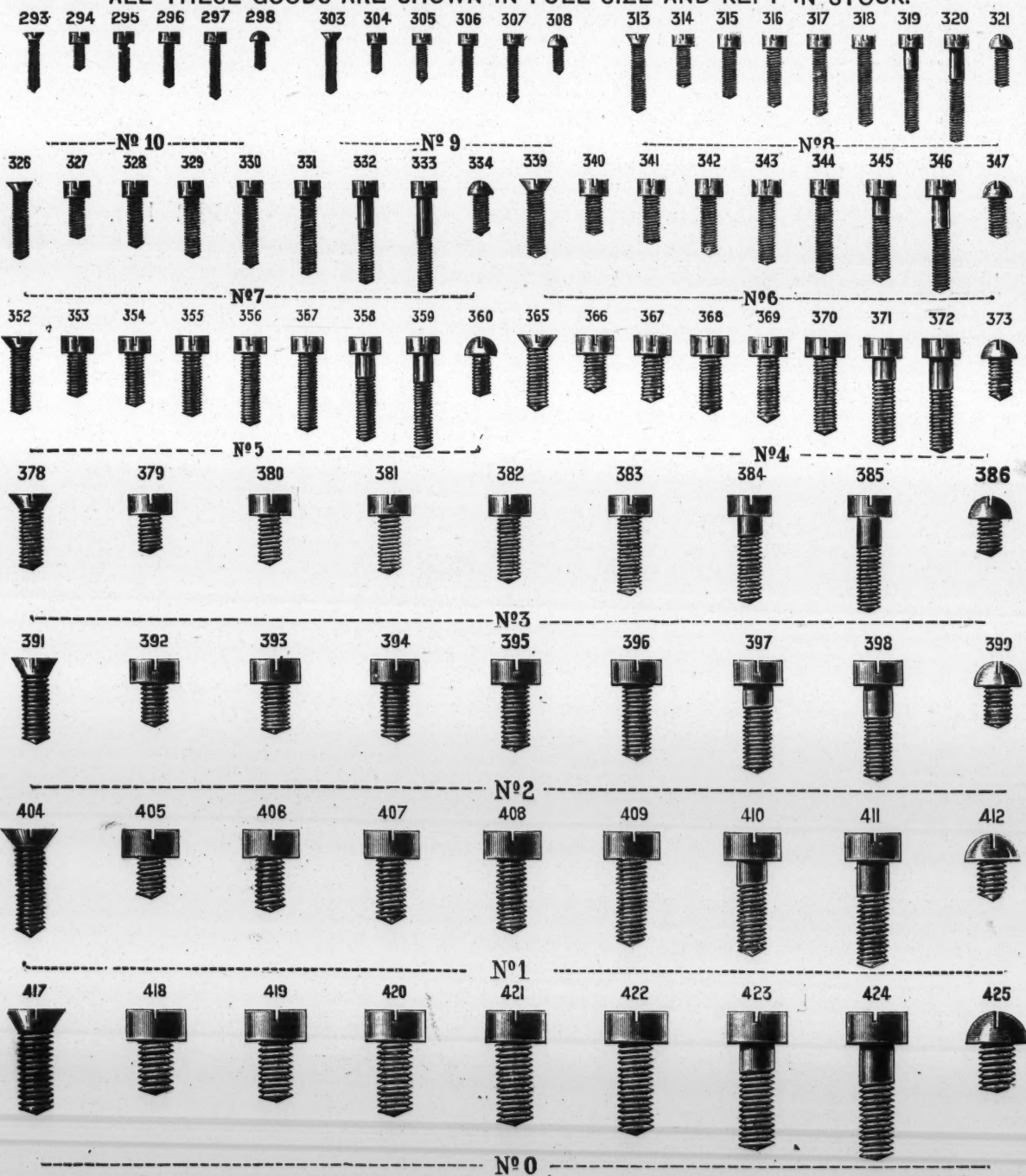
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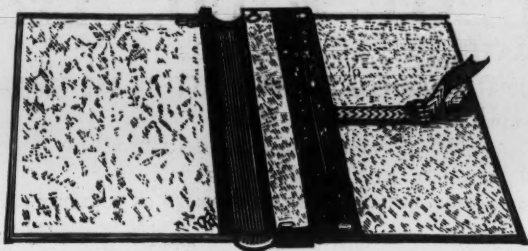
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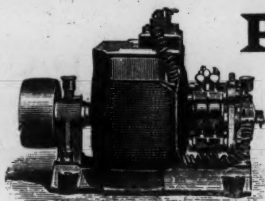
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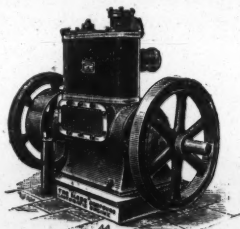
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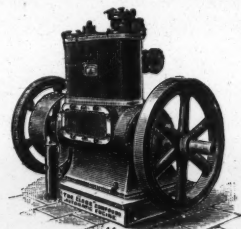
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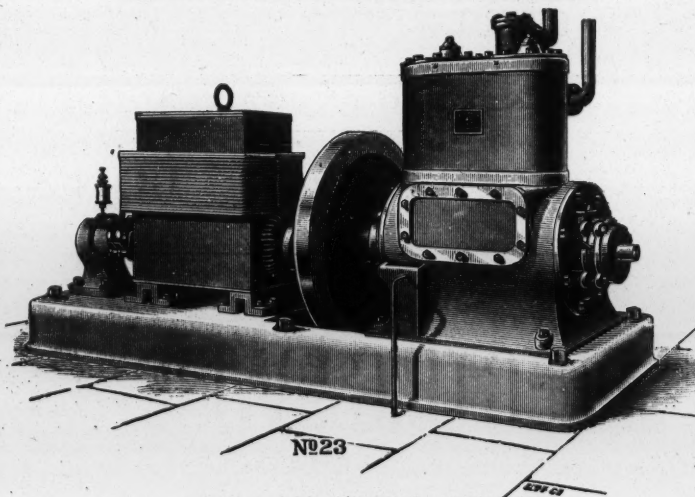
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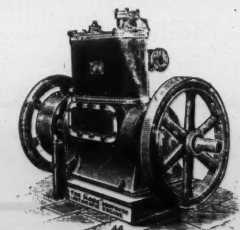
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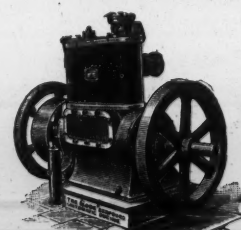
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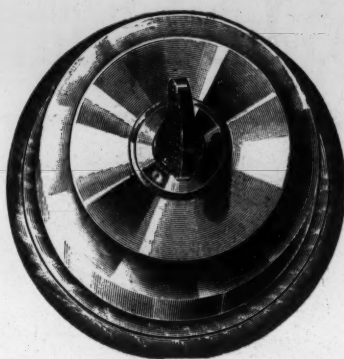
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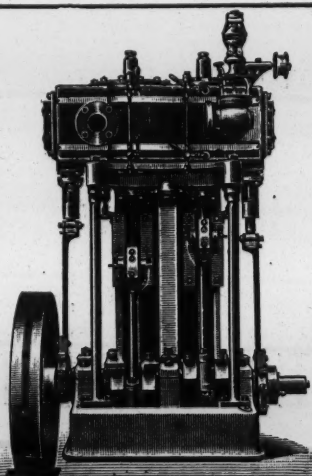
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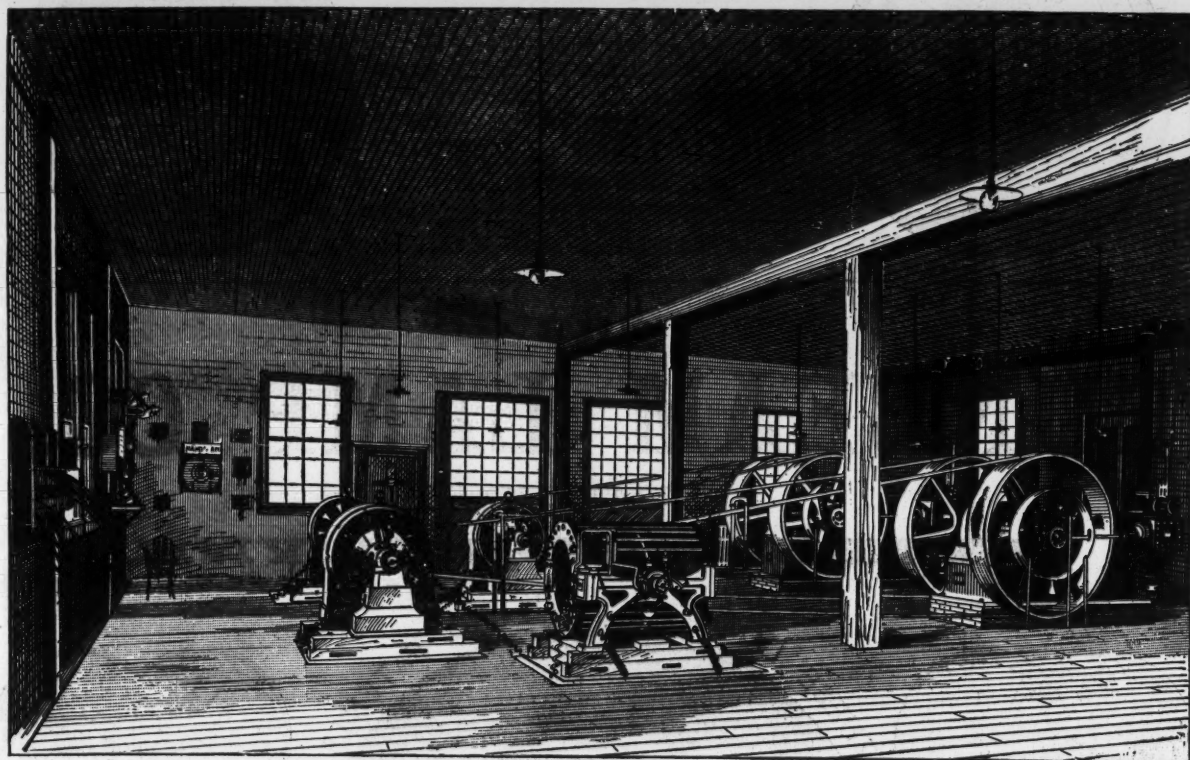
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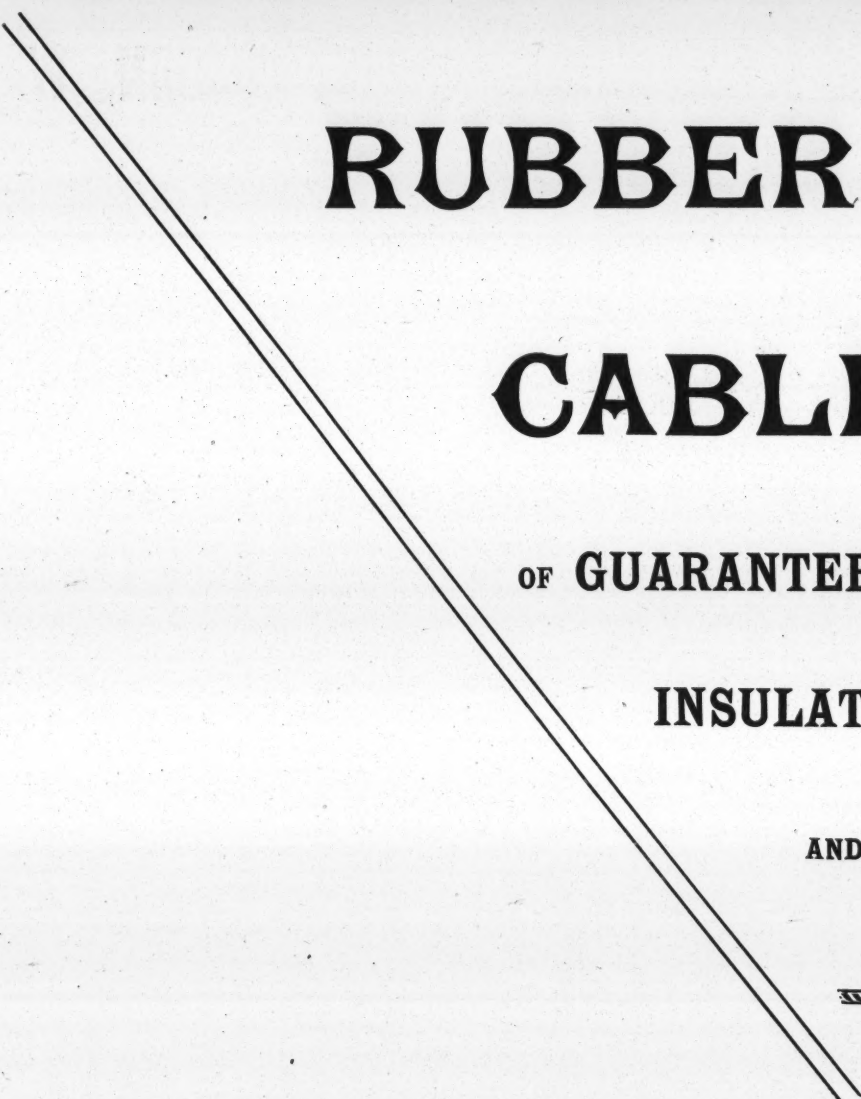
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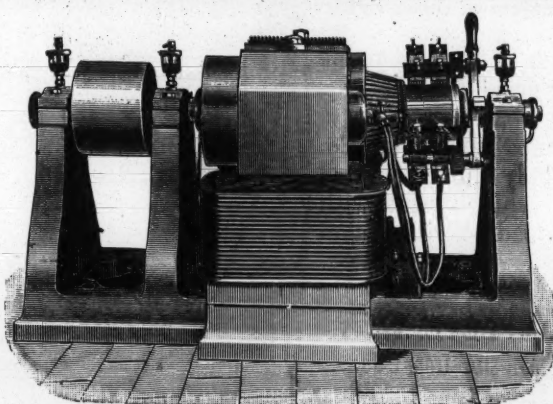
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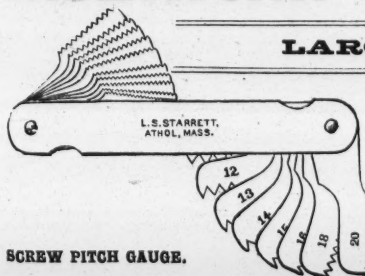
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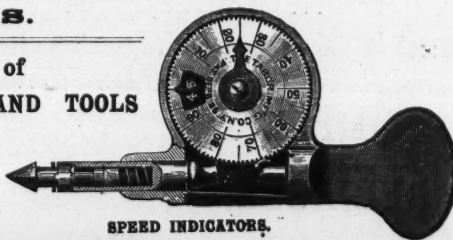
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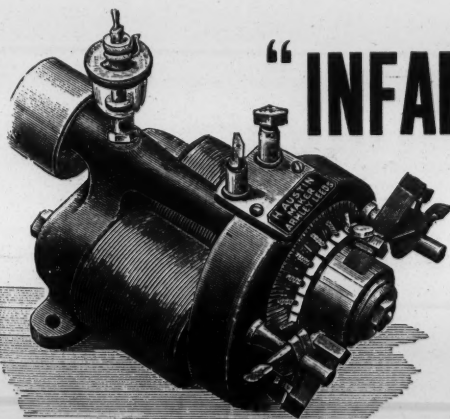
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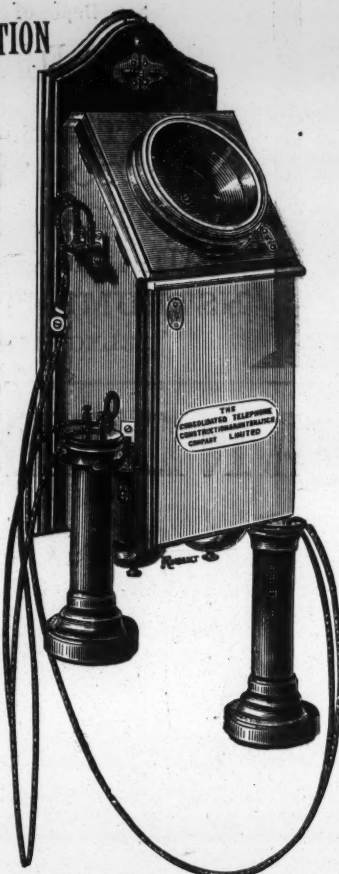
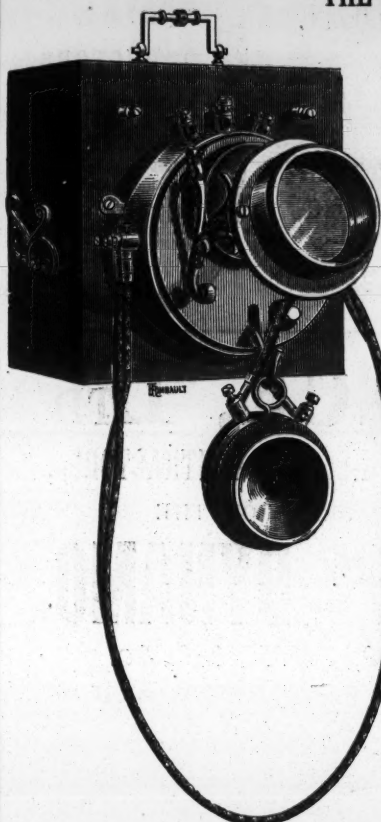
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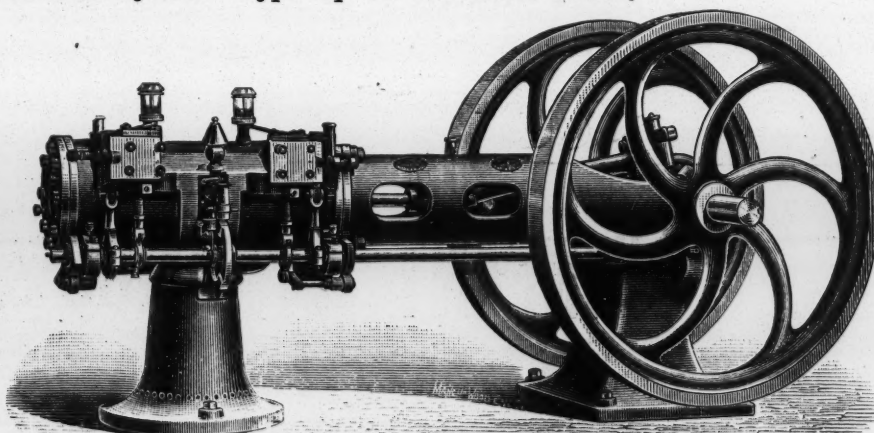
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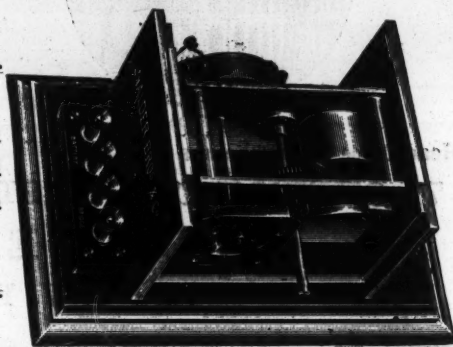
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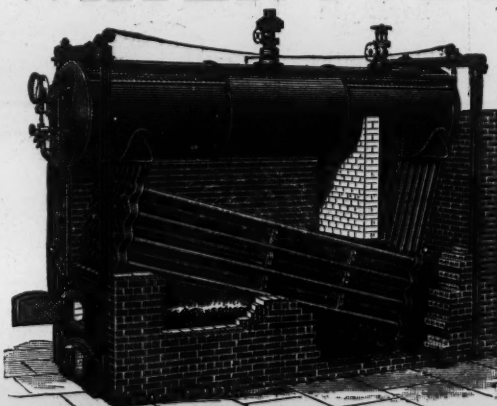
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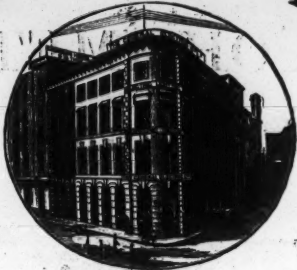
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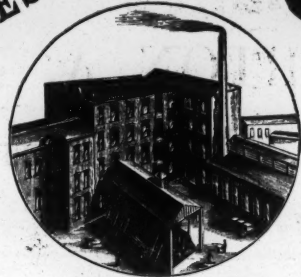
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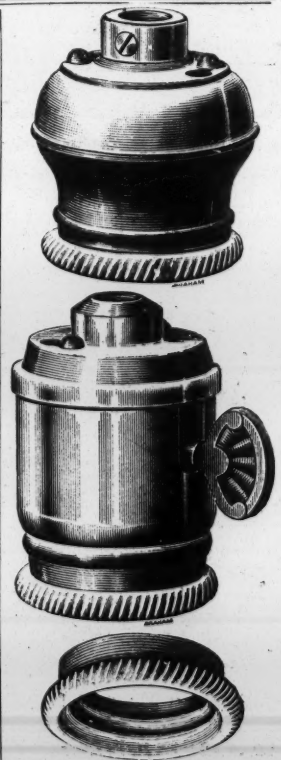
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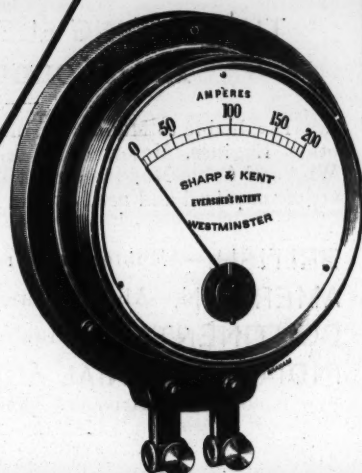
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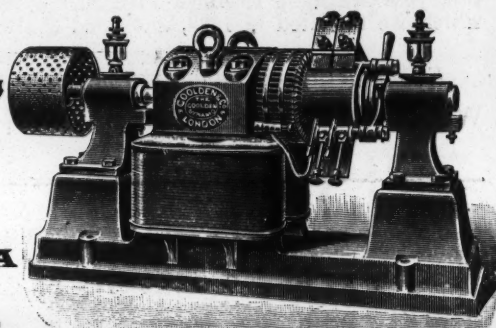
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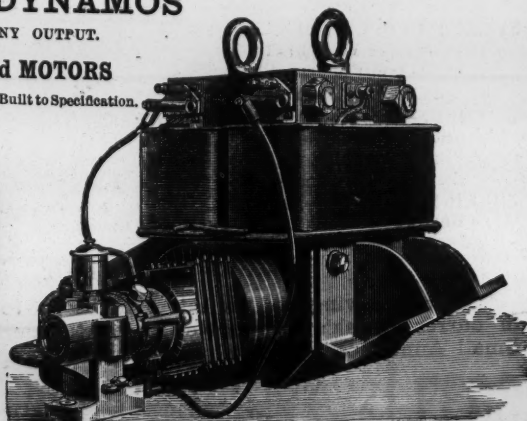
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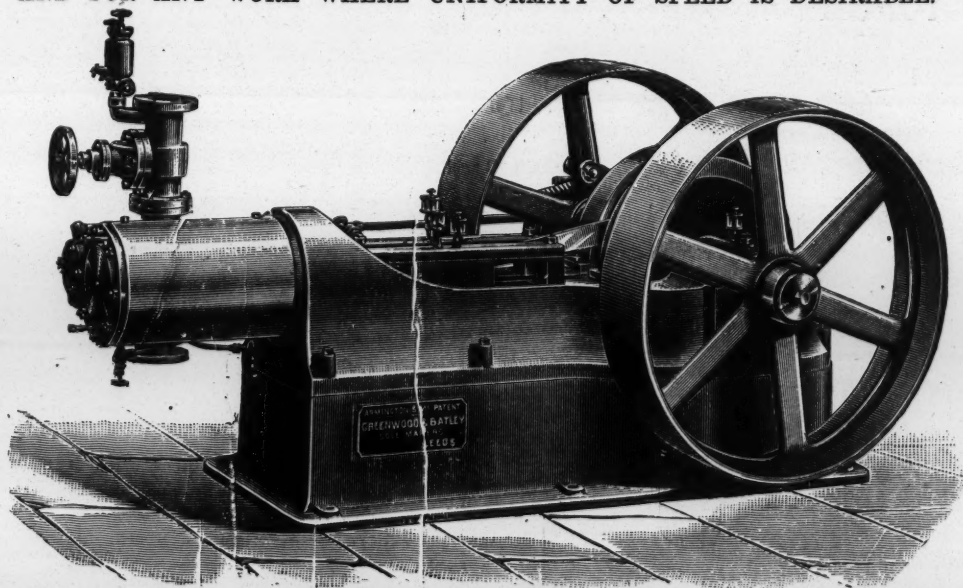
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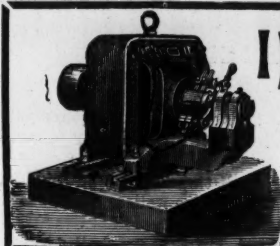
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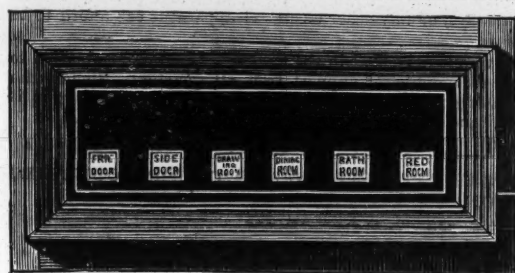
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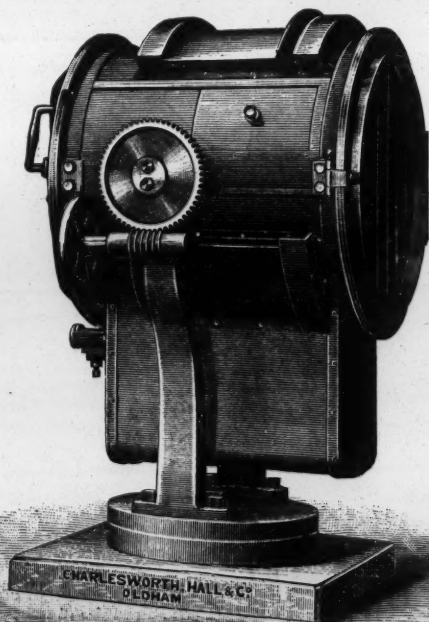
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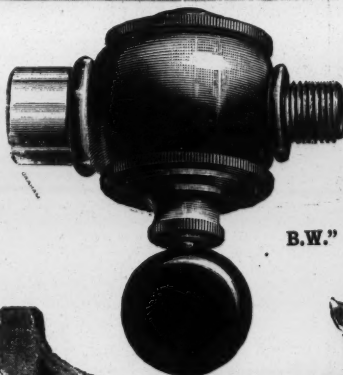
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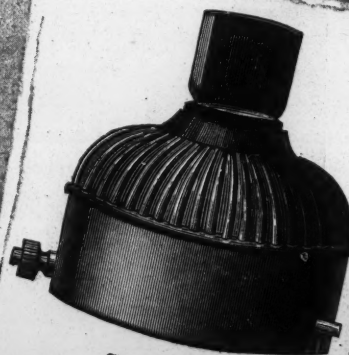
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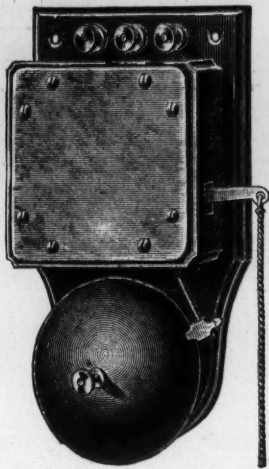
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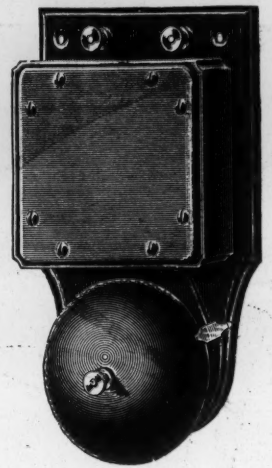
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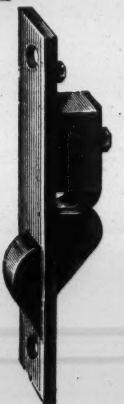
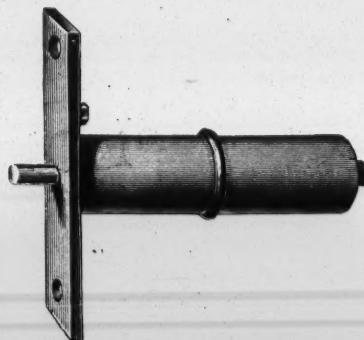
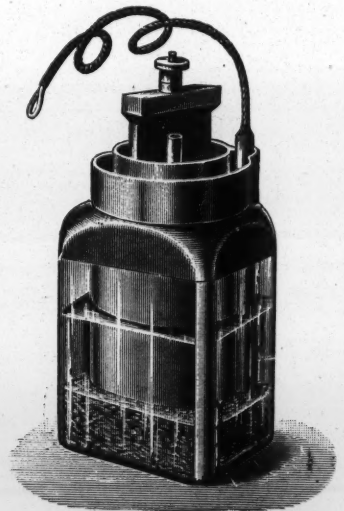
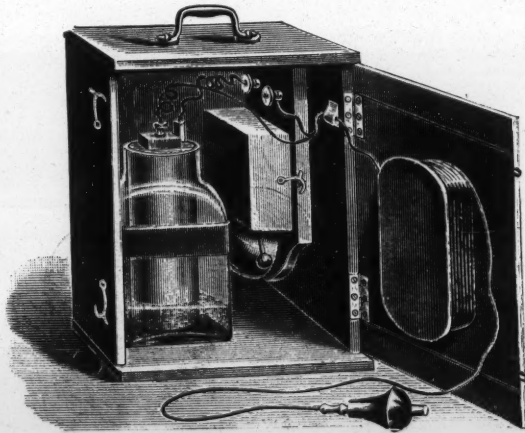
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